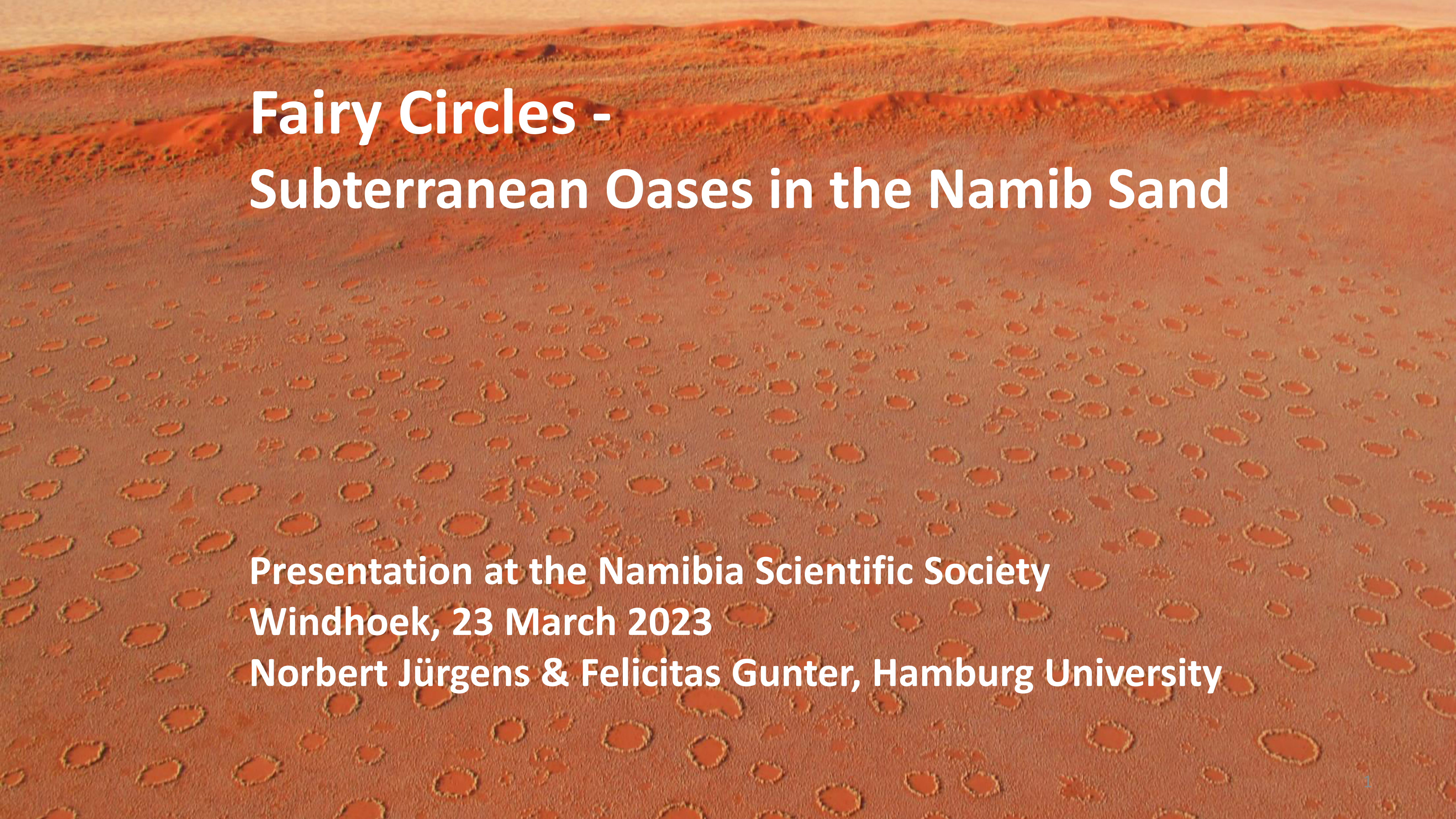
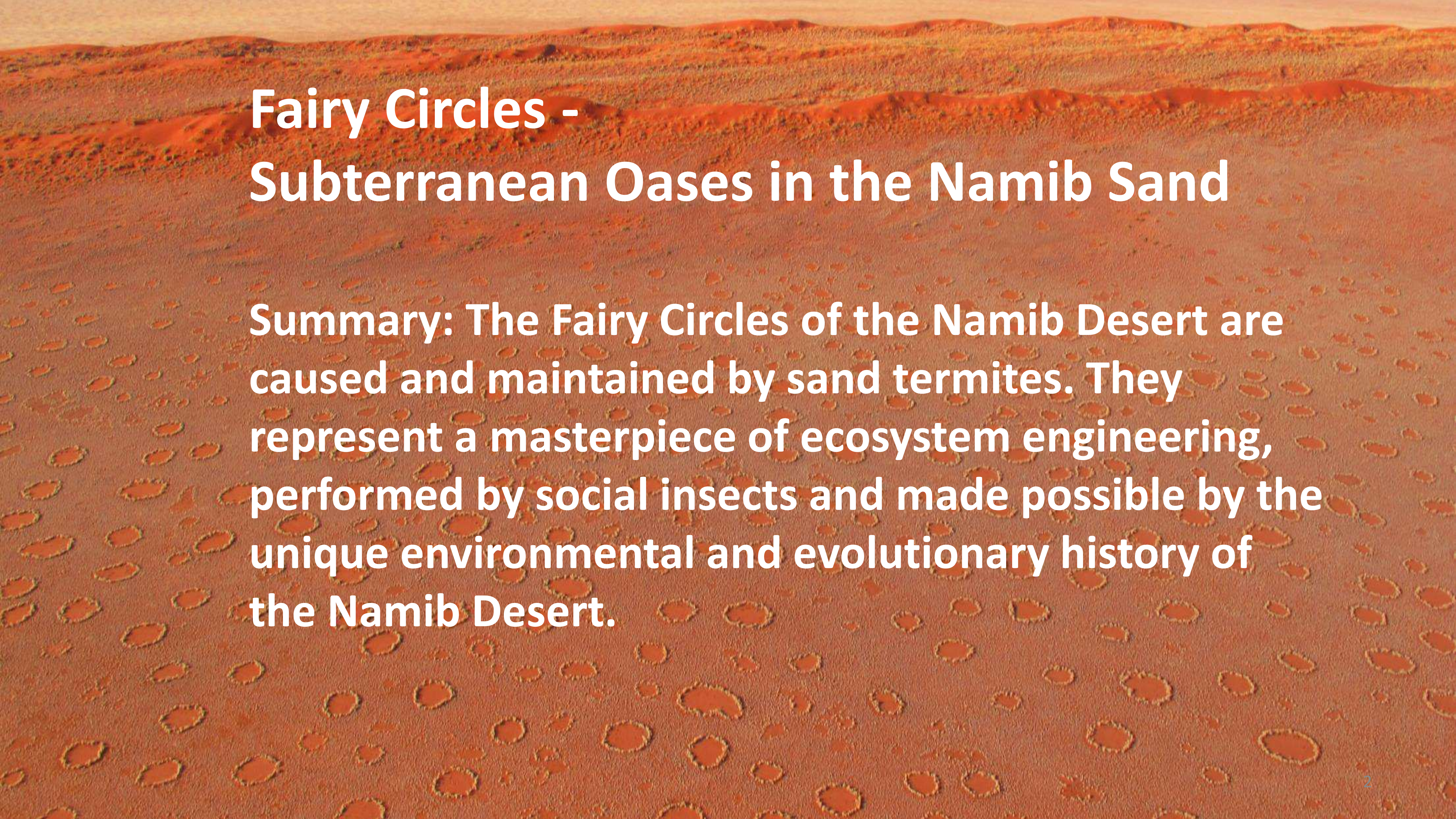


Fairy Circles -
Subterranean Oases in the Namib Sand

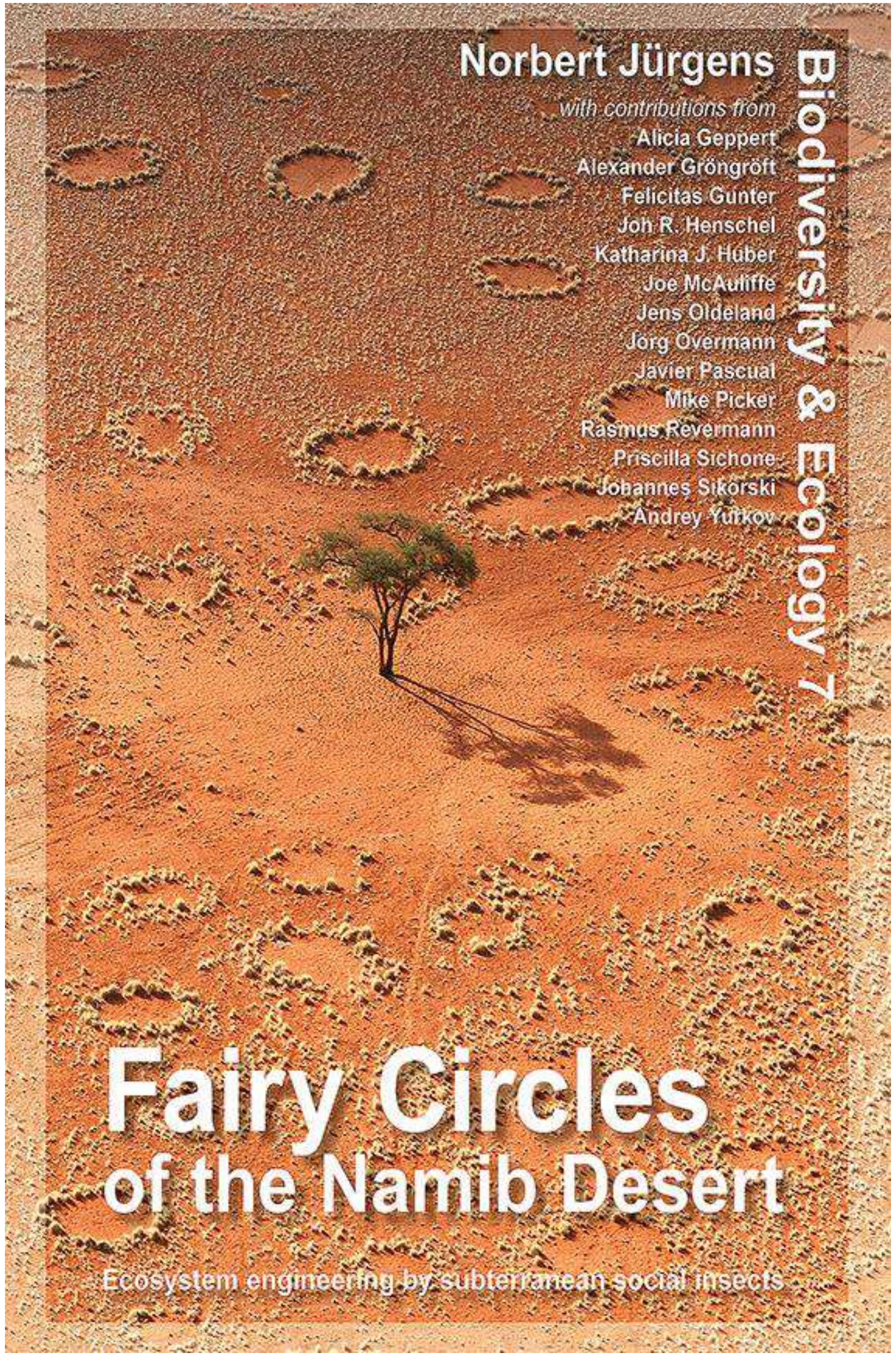
Presentation at the Namibia Scientific Society
Windhoek, 23 March 2023

Norbert Jürgens & Felicitas Gunter, Hamburg University



Fairy Circles -
Subterranean Oases in the Namib Sand

Summary: The Fairy Circles of the Namib Desert are caused and maintained by sand termites. They represent a masterpiece of ecosystem engineering, performed by social insects and made possible by the unique environmental and evolutionary history of the Namib Desert.



The Biological Underpinnings of Namib Desert Fairy Circles

Norbert Juergens

The sand termite *Psammotermes allocerus* generates local ecosystems, so-called fairy circles, through removal of short-lived vegetation that appears after rain, leaving circular barren patches. Because of rapid percolation and lack of evapotranspiration, water is retained within the circles. This process results in the formation of rings of perennial vegetation that facilitate termite survival and locally increase biodiversity. This termite-generated ecosystem persists through prolonged droughts lasting many decades.

2013 Science
2013 Reprint by the Namibia Scientific Society

The new book is a much wider monograph, 376 pages , more than 700 figures and tables, 15 co-authors from Microbiology, Soil Science, Molecular Genetics, Entomology, Botany, Ecology, going far beyond fairy circles.
Thanks to 14 anonymous reviewers!

Focus tonight is on sand termites and fairy circles. Open for discussion after the presentation. Excursions for in-depth discussions and demonstrations.

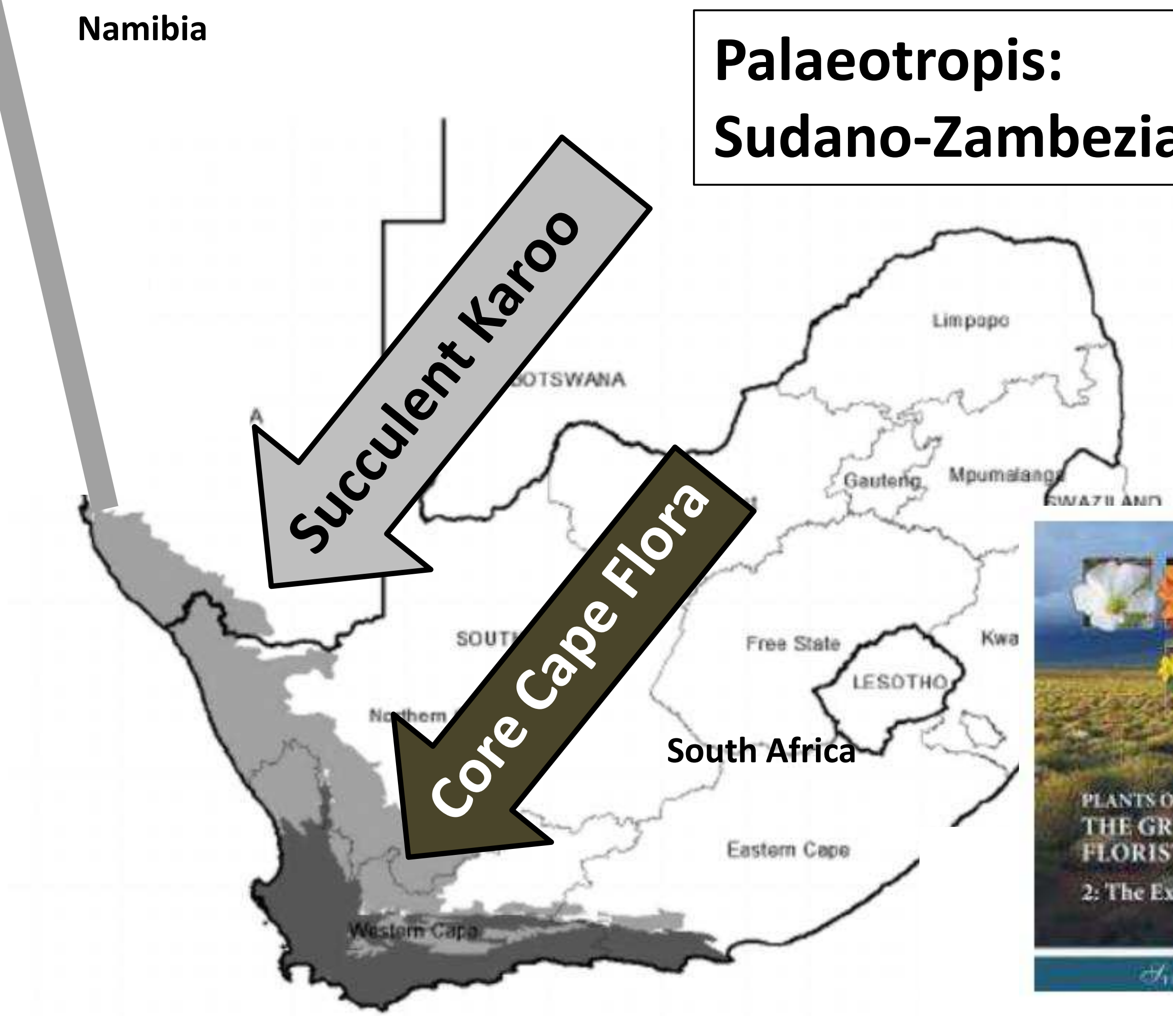
Prof Dr Norbert Jürgens, U Hamburg,
Institute of Plant Sciences and Microbiology (IPM)
Head of Research Group Biodiversity, Ecology, Evolution
& Director Herbarium Hamburgense (2000-2022)
1.8 Mio(!) plant specimen
World-largest greenhouse collection of Aizoaceae

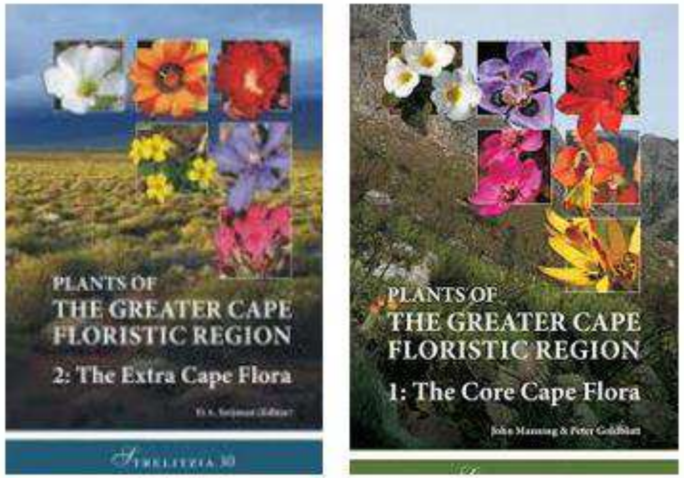
Previous research: Biogeography of the Namib

Greater Cape Flora

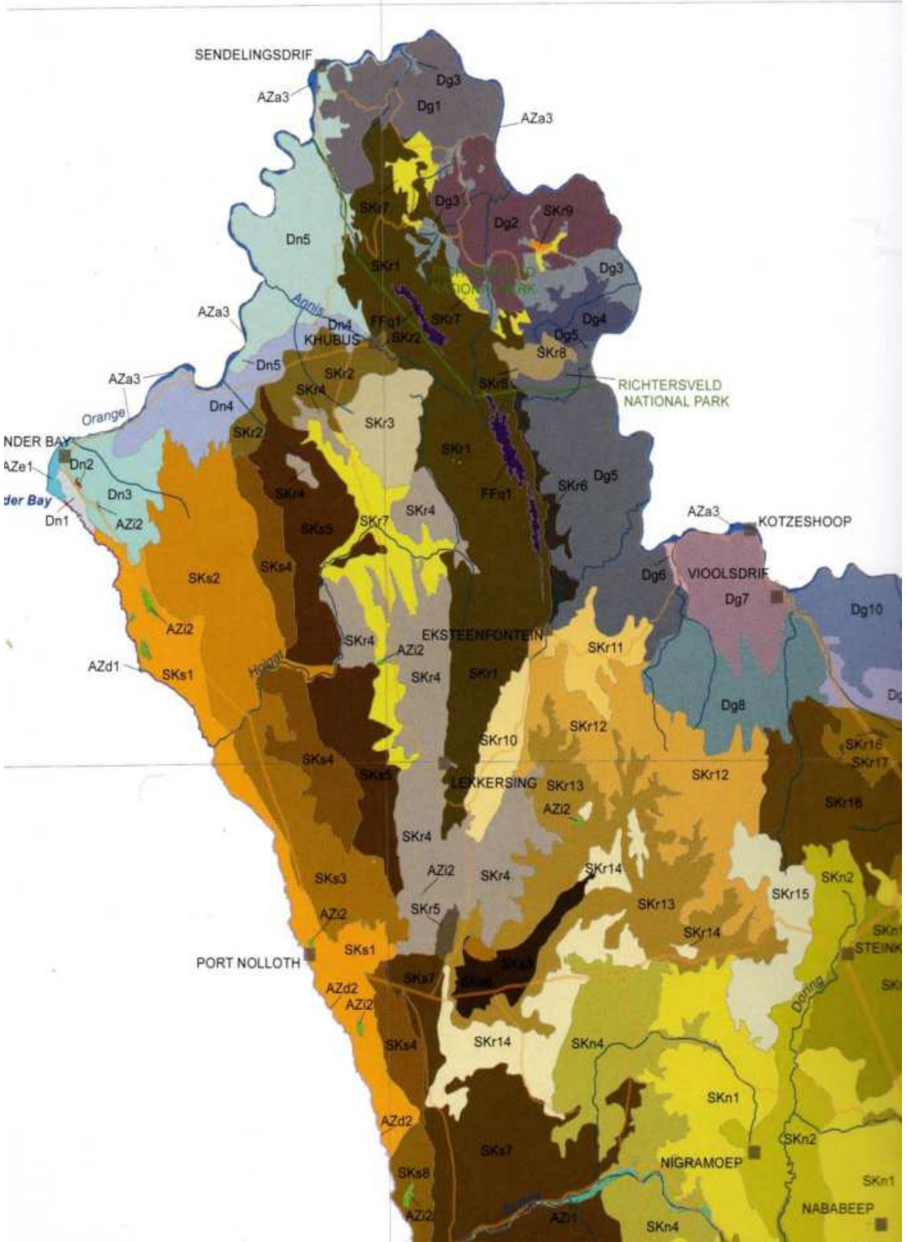
Jürgens 1991: A new approach to the Namib Region: Vegetatio 97:21-38,
Jürgens 1997: Floristic Biodiversity and history of African arid regions: Biodiversity & Conservation 6: 495-514

Palaeotropis:
Sudano-Zambezian Region





Vegetation map of South Africa 2006



Desert Biome

Norbert Jürgens

with contributions by

Philip G. Desmet, Michael C. Rutherford, Ladislav Mucina and Robert A. Ward

Table of Contents

List of Vegetation Units

Succulent Karoo Biome

Ladislav Mucina, Norbert Jürgens, Annelise le Roux, Michael C. Rutherford, Ute Schmiedel, Karen J. Esler, Leslie W. Powrie, Philip G. Desmet and Susanne J. Milton

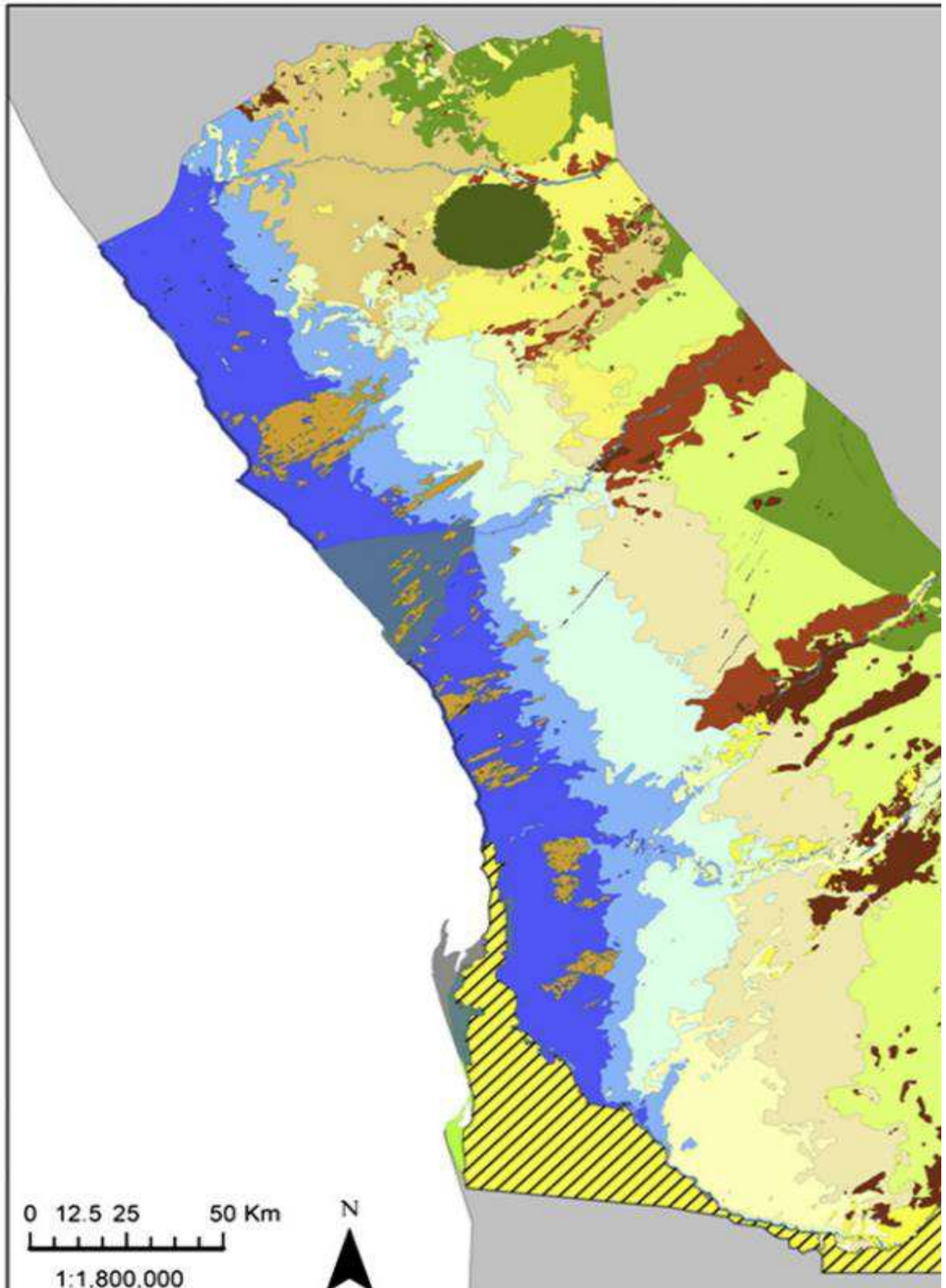
with contributions by

Charles Boucher, Freddie Ellis, Jan J.N. Lambrechts, Robert A. Ward, John C. Manning and Guy F. Midgley

Table of Contents

List of Vegetation Units

Previous research: Vegetation classification and map of the Namib - 2012



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Contents lists available at SciVerse ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

Arid Environments

Ecology and spatial patterns of large-scale vegetation units within the central Namib Desert

N. Juergens [a,*], J. Oldeland [a], B. Hachfeld [a], E. Erb [b], C. Schultz [c]

Coastal zones

- 05 - *Salsola* – *Arthraerua* coastal desert plain shrublands
- 06 - *Zygophyllum* – *Brownanthus* beach succulent dwarf shrublands
- 07 - *Arthraerua* dominated fog belt shrublands
- 07 - *Arthraerua* dominated fog belt shrublands with Lichen fields (a - e)
- 08 - *Arthraerua* – *Zygophyllum* coastal plains succulent shrublands
- 10 - *Arthraerua* – *Zygophyllum* – *S. ciliata* transitional shrub- and grasslands

Grassland zones

- 11 - Species-poor *S. ciliata* – *S. gonatostachys* central desert plains grasslands
- 12 - *S. obtusa* central calcrete desert plains grasslands
- 13 - *E. nindensis* eastern calcrete plains grasslands
- 14 - *S. hirtigluma* desert plains grasslands
- 16 - *S. hirtigluma* – *Commiphora* stony and rocky desert grasslands
- 17 - *S. uniplumis* eastern grasslands
- 19 - *Euphorbia* – *S. hochstetteriana* dune grass- and succulent shrublands
- 20 - *S. hochstetteriana* eastern desert plains grasslands

Shrubland and Savanna zones

- 15 - *Calicorema* – *Commiphora* rocky shrublands
- 18 - *Euphorbia* – *Stipagrostis* northeastern dune grass- and succulent shrublands
- 21 - *Acacia* – *Colophospermum* eastern desert plains and hills savanna transition

Azonal units

- 01 - *S. sabulicola* – *Cladoraphis* mobile dune grasslands
- 02 - *Faidherbia* – *Acacia* large ephemeral river riparian woodlands
- 04 - *Odyssea paucinervis* salt marsh
- 09 - *Euphorbia* – *Pelargonium* coastal dolerite hill succulent shrublands
- 22 - Brandberg mountain vegetation
- 23 - Sandwich Harbour Lagoon
- 24 - Walvis Bay (urban area and Pelican Point)

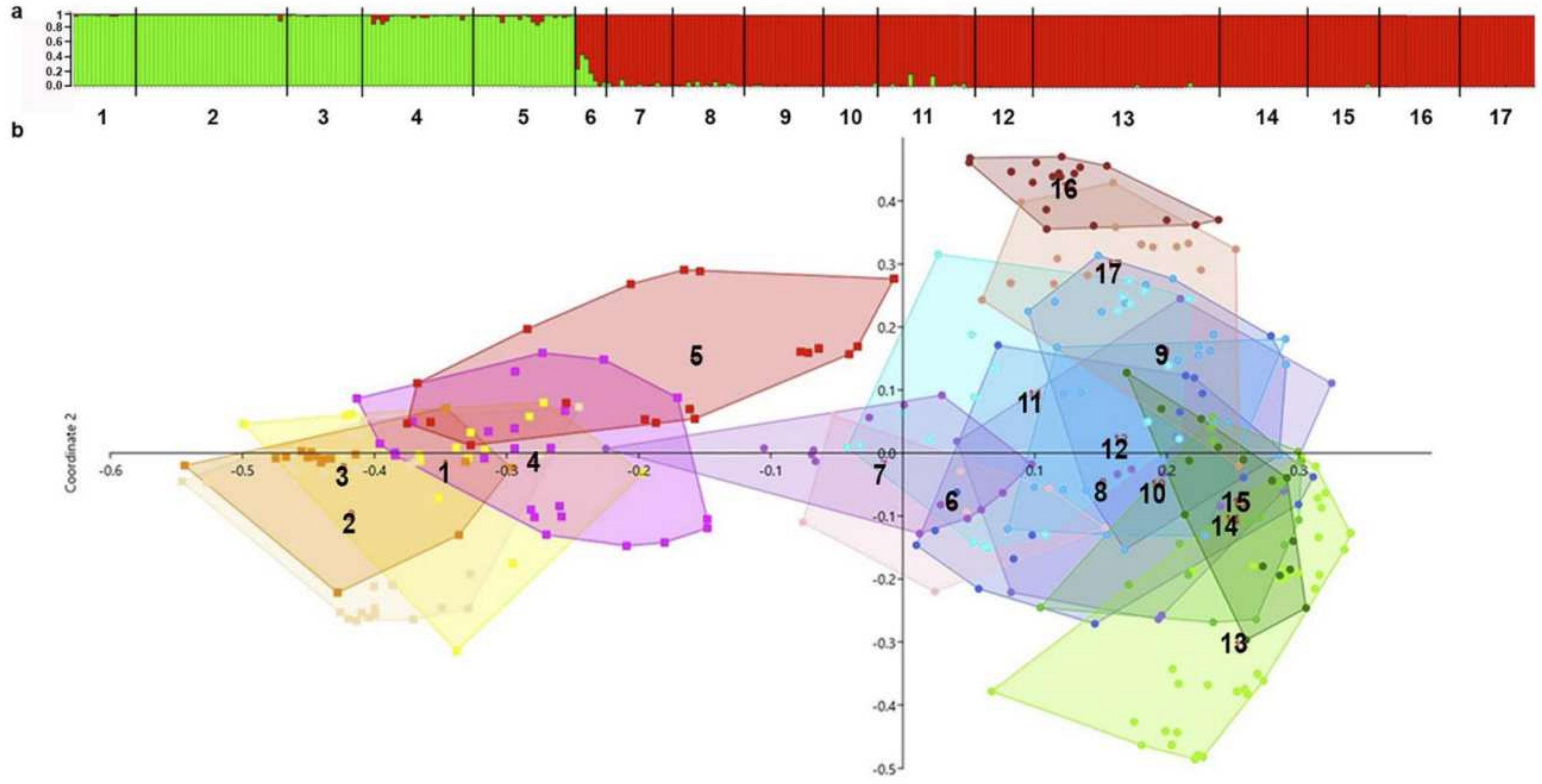
Previous research: Evolution & phylogeography of Namib plants - 2021

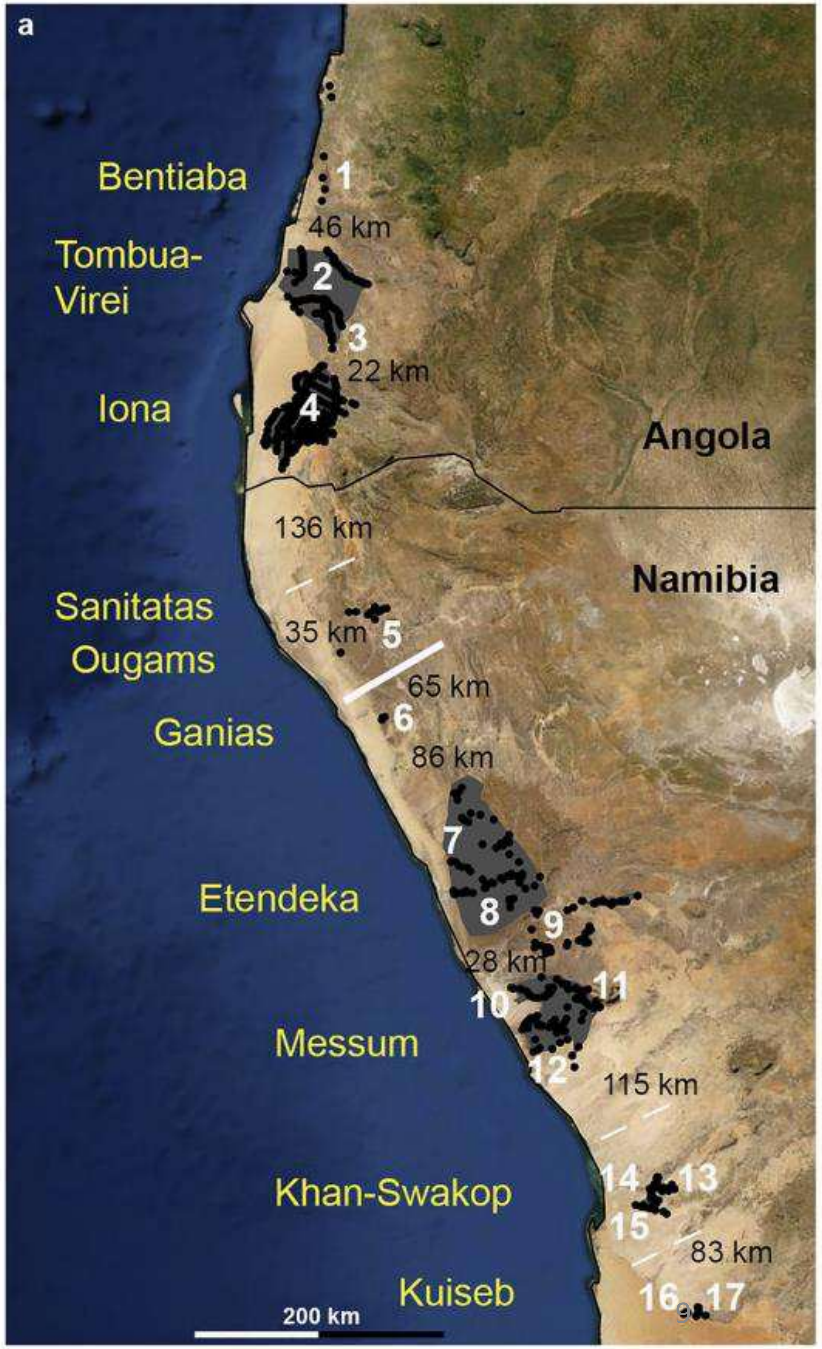
www.nature.com/scientificreports

Welwitschia: Phylogeography of a living fossil, diversified within a desert refuge

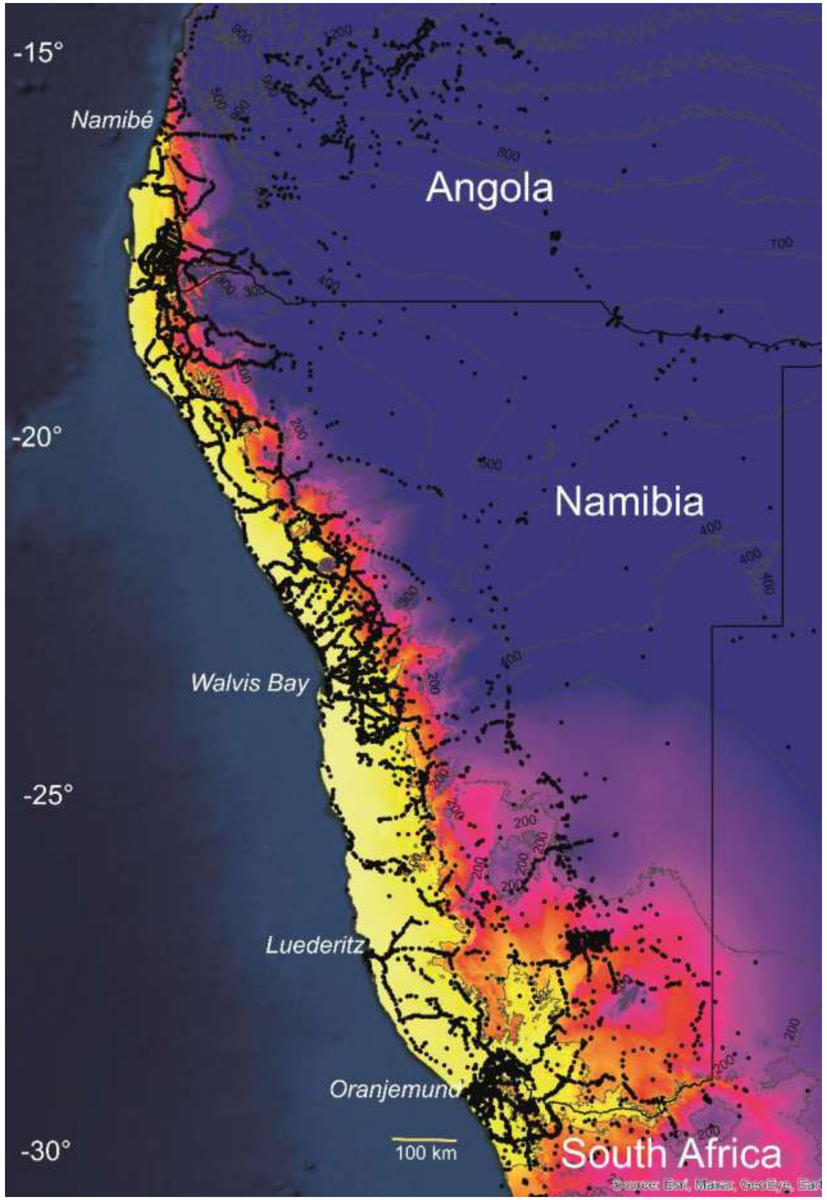
Norbert Jürgens✉, Imke Oncken, Jens Oldeland, Felicitas Gunter & Barbara Rudolph

Two subspecies of Welwitschia in Namibia!





Namib Desert studies: Comprehensive and repeated careful field observation and experiments, spanning more than 43 years

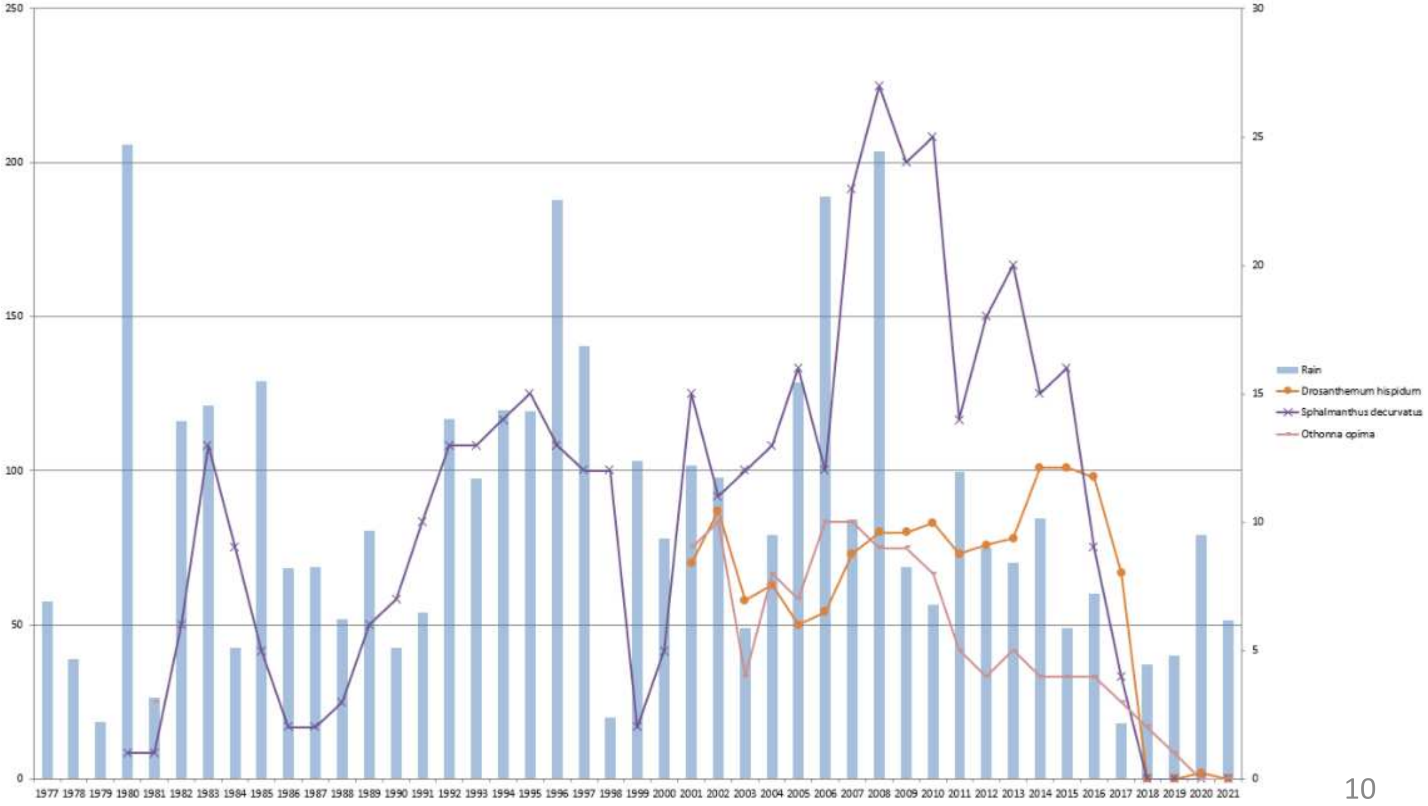


A: SPACE

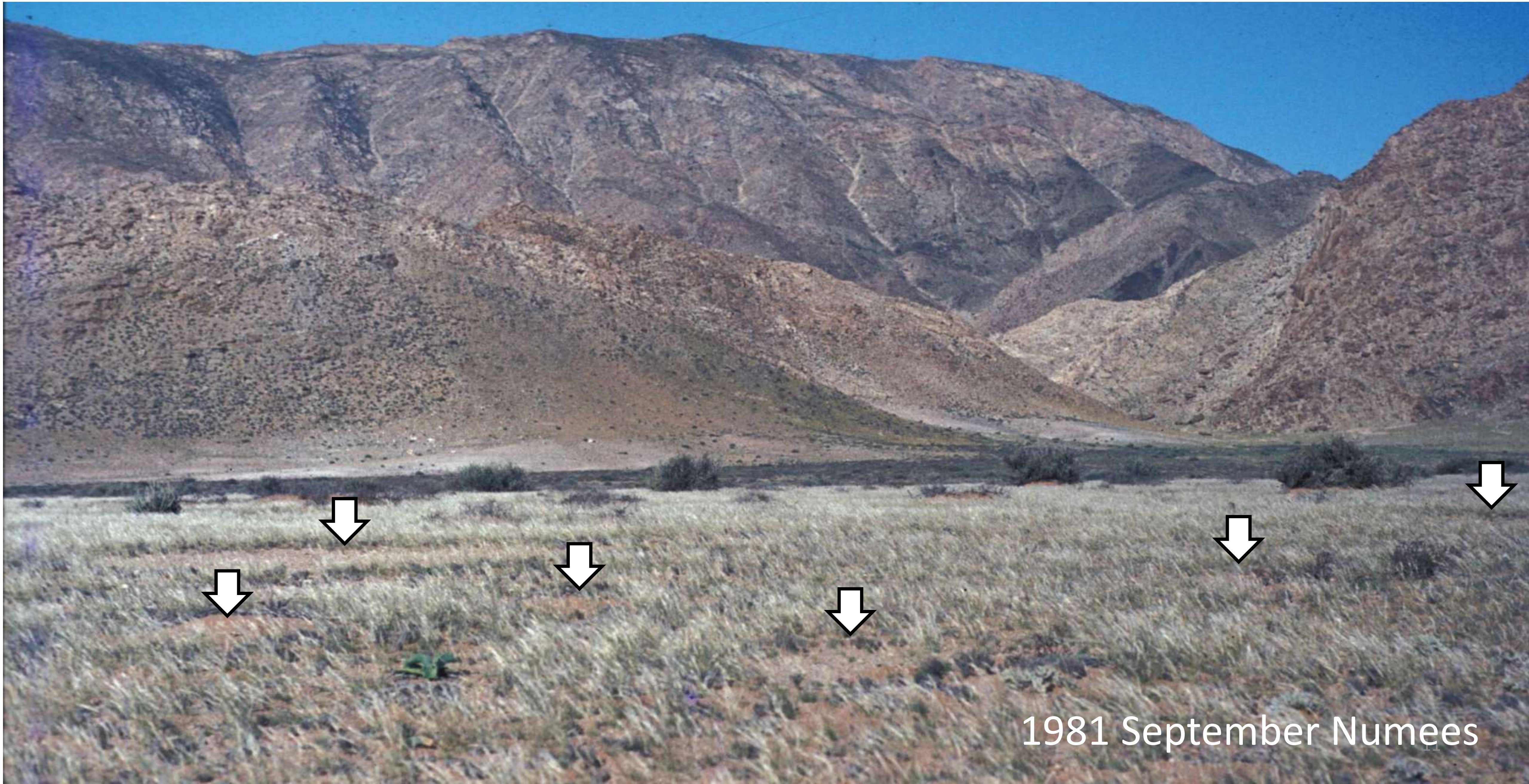
Spatial vegetation data: 20.884 releves of 1.000m², 1872 FC (14.03.2023)

B: TIME

Time series: (since February 1980)



My first fairy circles, annually observed since February 1980

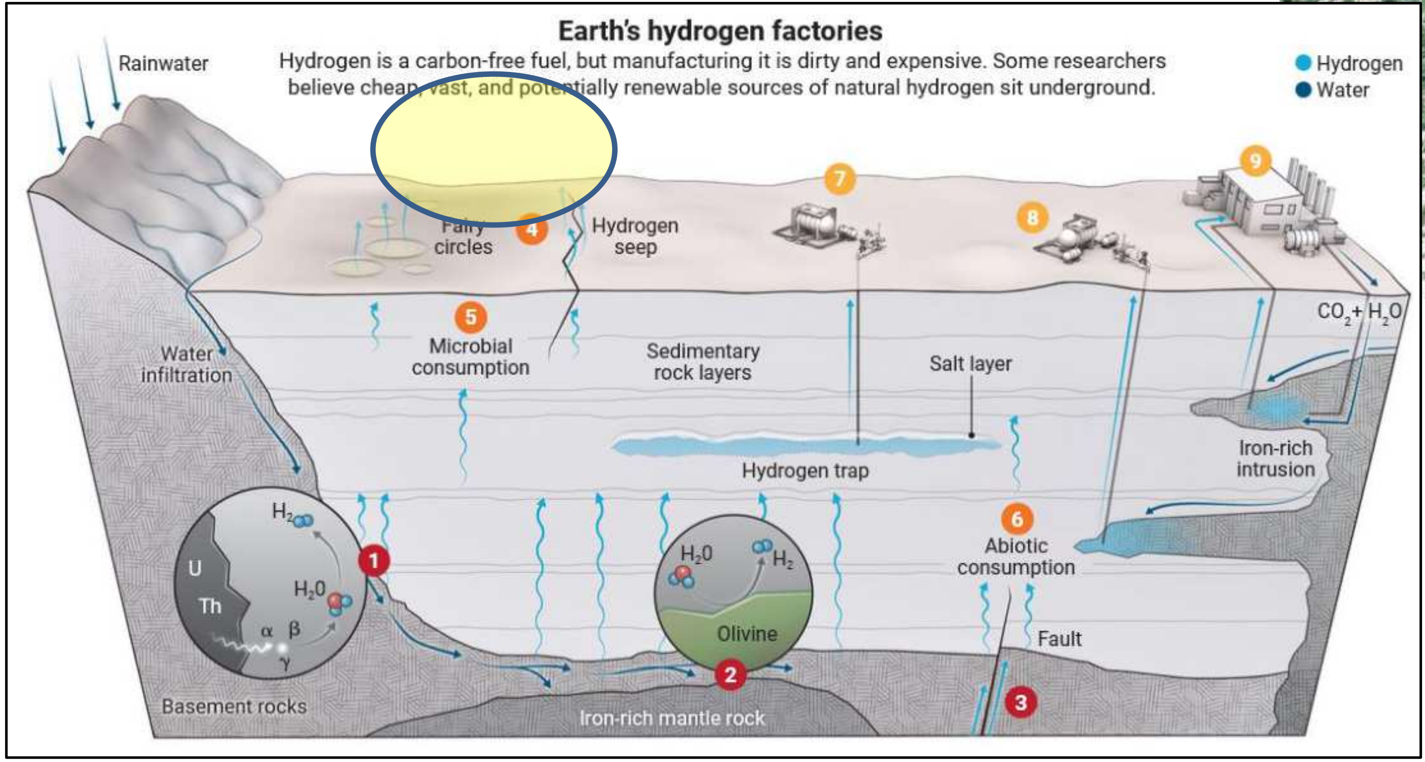


More hypotheses than fairies

- Effects of dead Euphorbia shrubs (Theron 1979, Meyer et al. 2015 and several more)
- Toxic gases (Jankowitz et al. 2008, Naude et al. 2011)
- Self-regulation hypothesis / swarm-intelligence of grasses (Tschinkel 2012, Cramer & Barger 2013, Getzin et al. 2015 and several more)
- Sand termites (Jürgens and co-authors 2013 and several more)

Fairy Circles!?

The term “fairy circle” is just too attractive: Many linguistic borrowings



02.03.2019: 36845, Zambezi Region

Hand, E.: Hidden hydrogen - Does Earth hold vast stores of a renewable, carbon-free fuel?
Science 10.02.2023 doi: 10.1126/science.adh1460

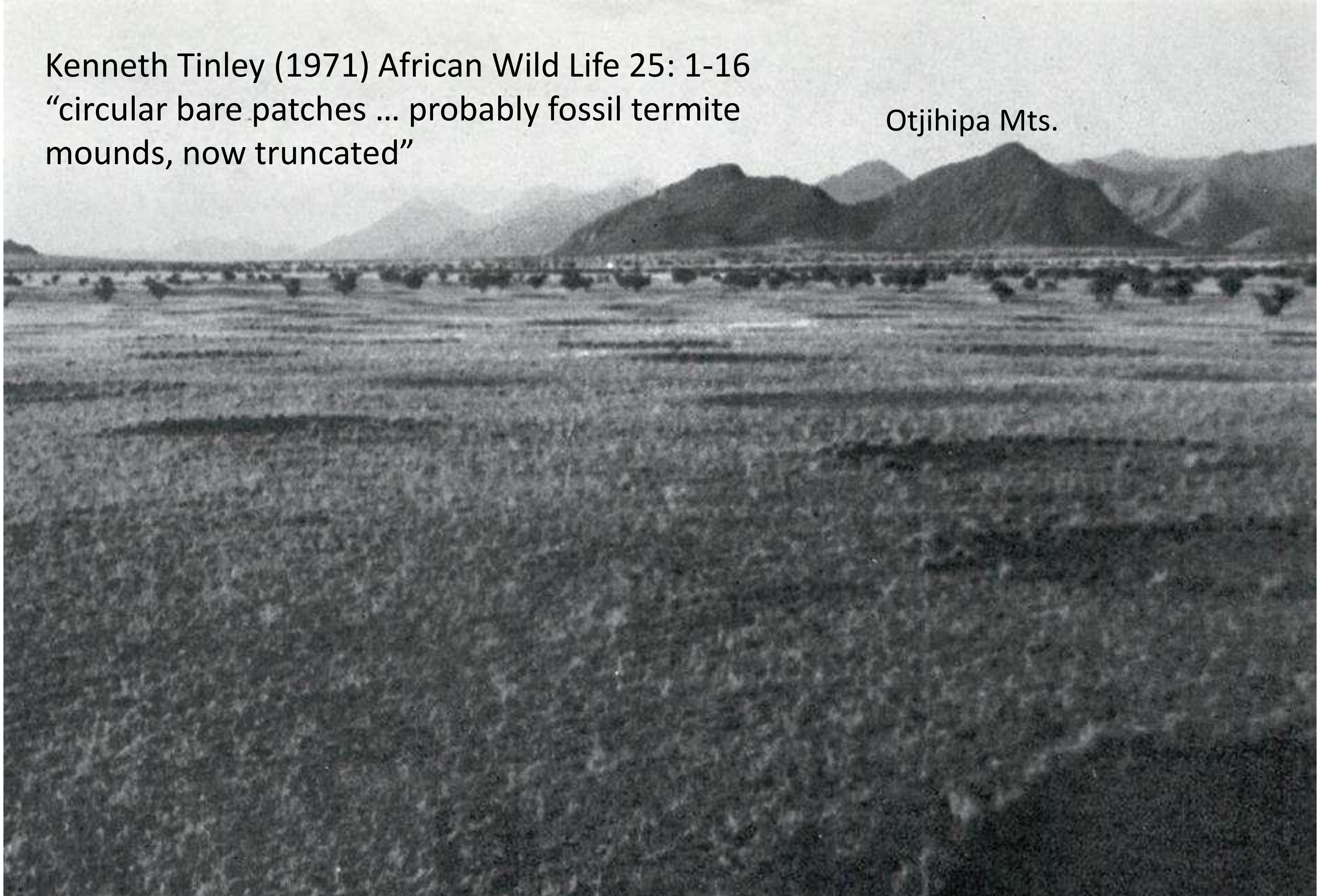
Question 1: What are “fairy circles”?

Discovery No. 1: 1971

Kenneth Tinley publishes a first photo of fairy circles (African Wild Life 25, 1971). “Type” principle

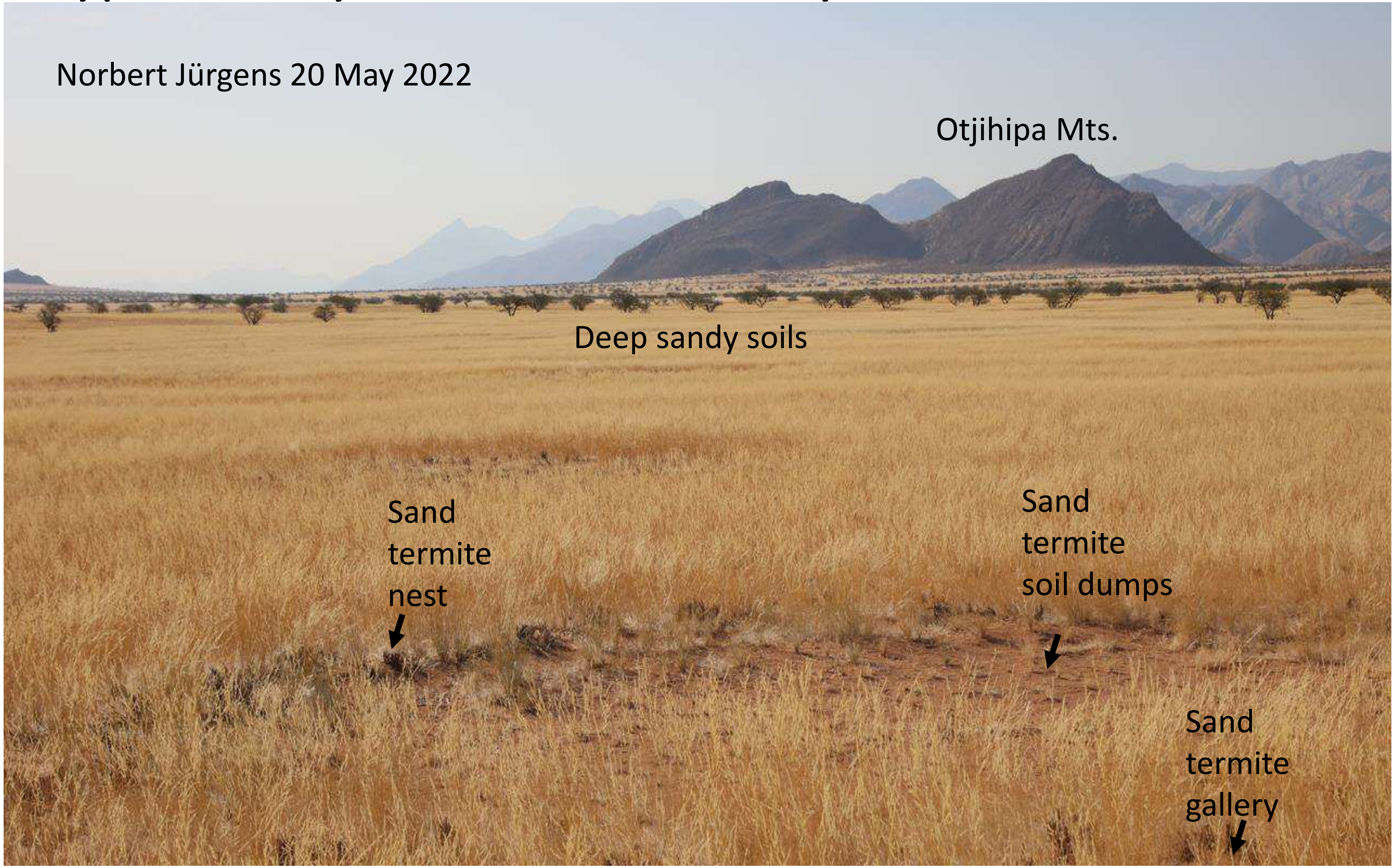
Type locality: Marienfluss Valley, NW Namibia,

Kenneth Tinley (1971) African Wild Life 25: 1-16
“circular bare patches … probably fossil termite mounds, now truncated”



Type locality: Marienfluss Valley, NW Namibia,

Type locality: Marienfluss Valley, NW Namibia,



Early publications, referring to the same fairy circles in the Kaokoveld, as first described by Tinley

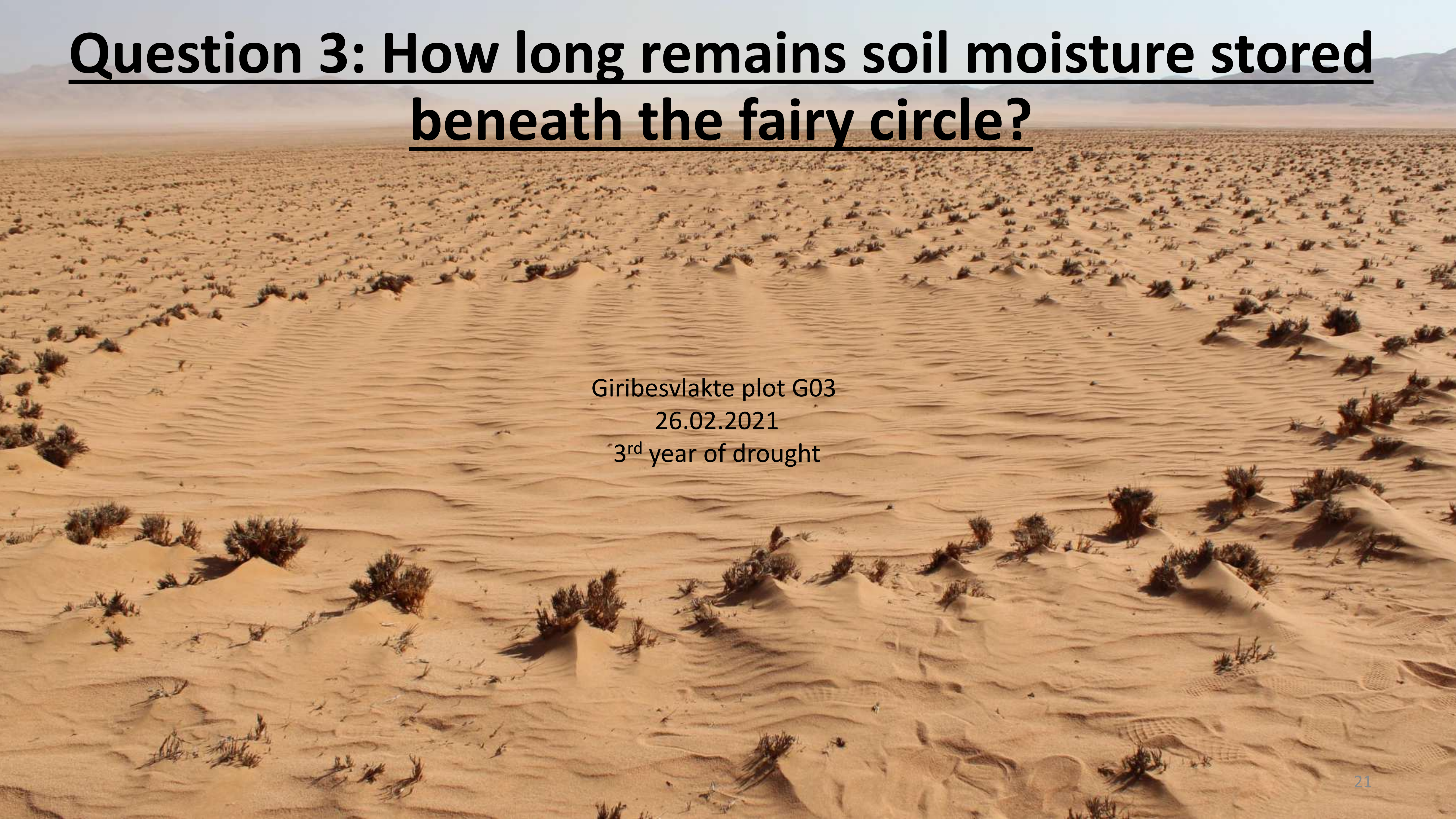
1971: Tinley: fossil termitaria
1979: Theron: Toxic Euphorbia remains!
1982: Eicker et al. Bacteria or fungi?
1994: Moll: ants or termites?
1997: Jürgens, Burke, Seely, Jacobsen: causes unknown
2000: Becker & Getzin: Harvester termite!
2001: Becker: Harvester termite!
2002: Grube: Against harvester termite
2004: Van Rooyen et al.: testing many hypotheses
2007: Becker: Harvester termite
2013: Jürgens: Sand termite!

Question 2: Do "fairy circles" have common environmental properties?

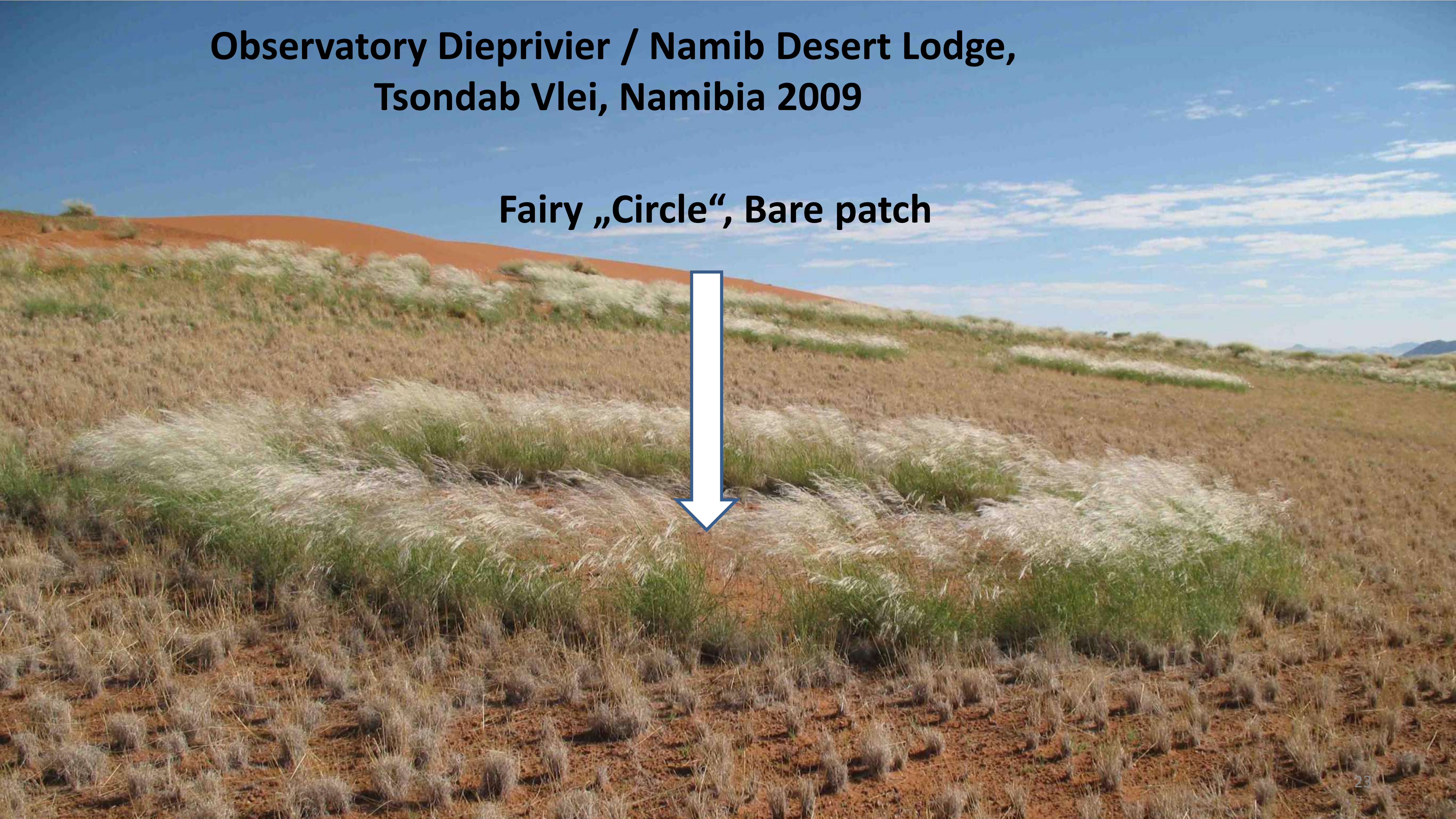
Discovery No. 2: 2001

Albrecht et al.: At the end of the rainy season (April) the soil beneath fairy circles is moister than the soil beneath matrix vegetation (South African Journal of Science, 2001)

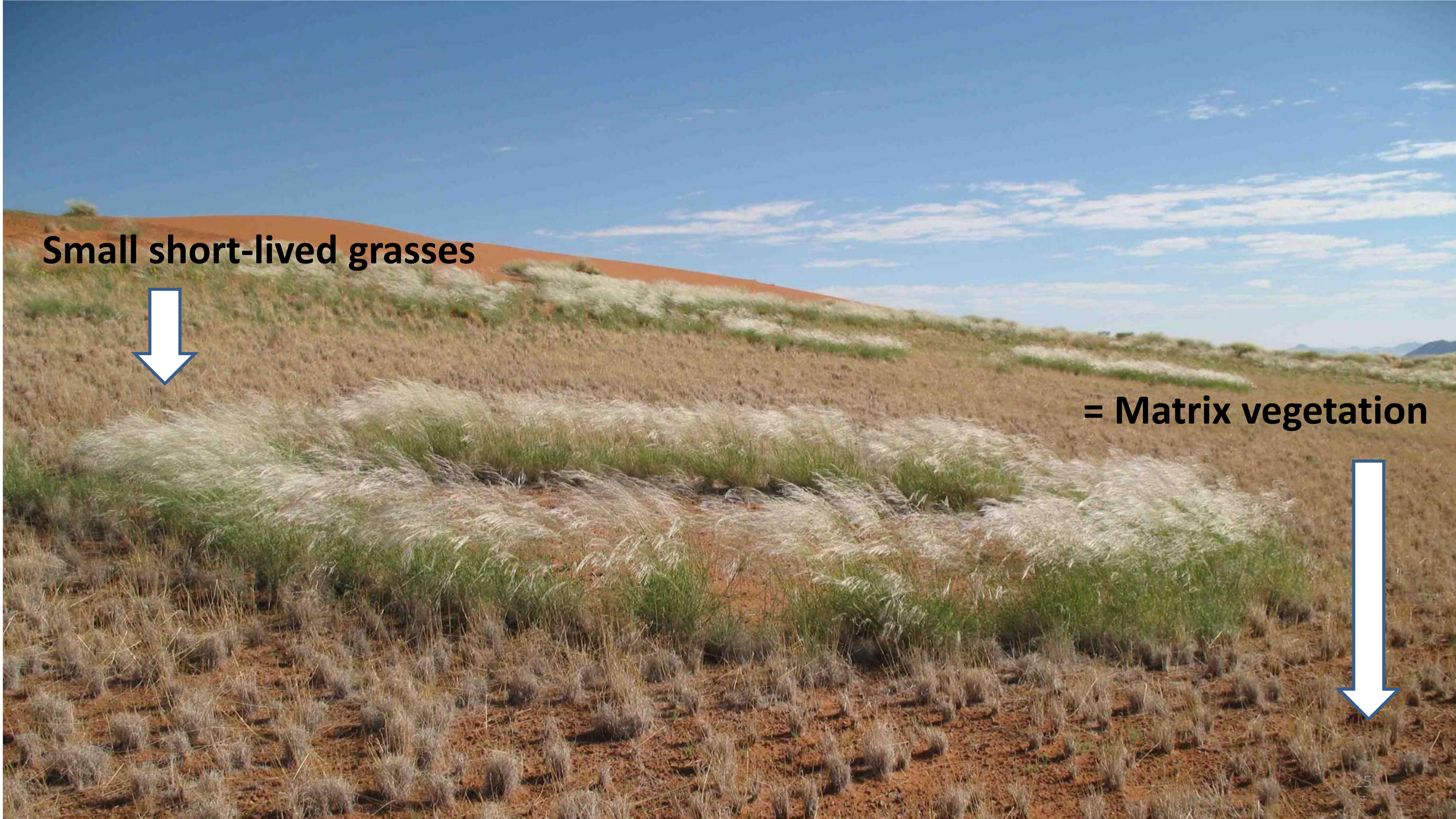
Question 3: How long remains soil moisture stored beneath the fairy circle?



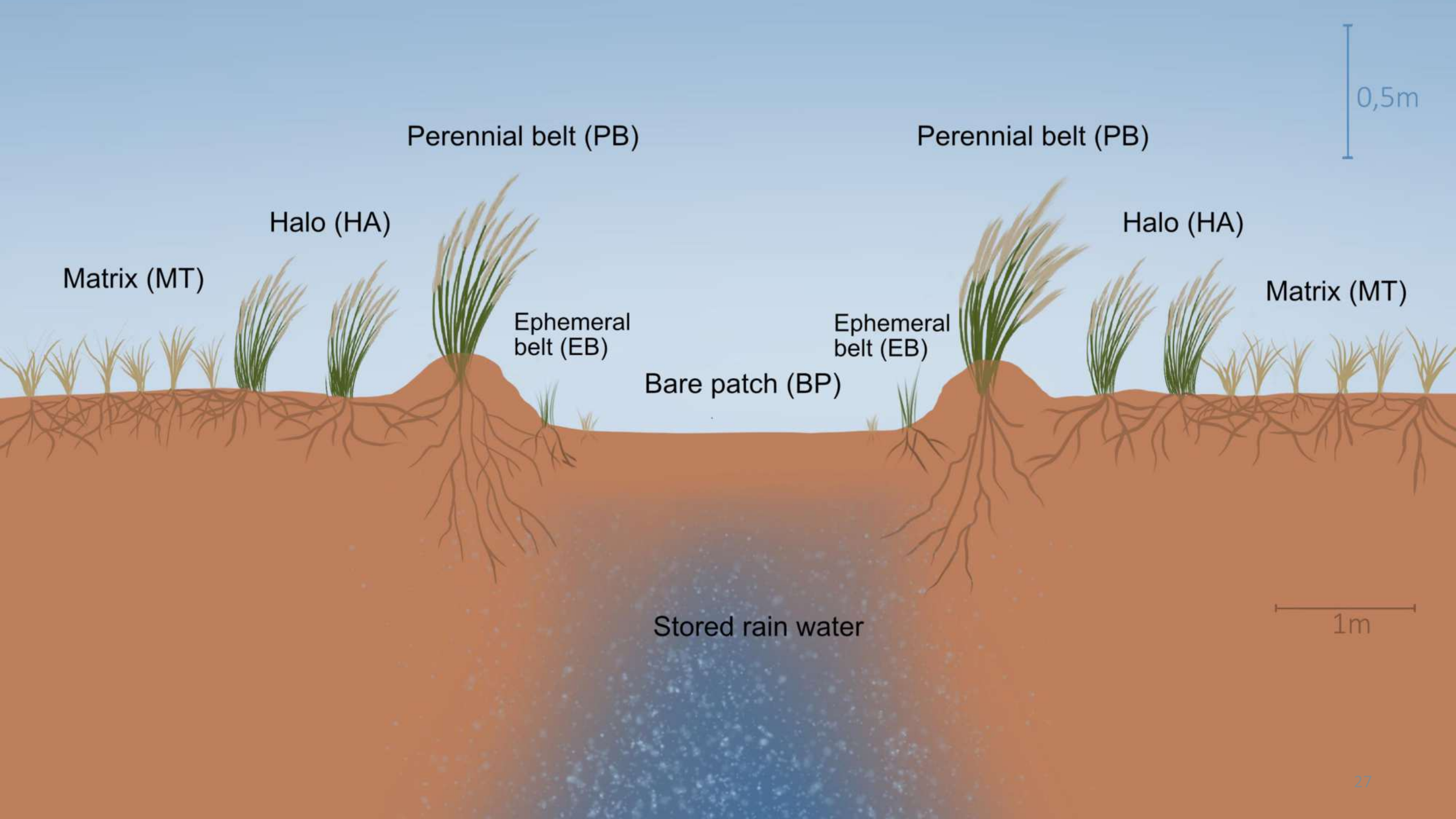
Giribesvlakte plot G03
26.02.2021
3rd year of drought


Observatory Dieprivier / Namib Desert Lodge,
Tsondab Vlei, Namibia 2009
Fairy „Circle“, Bare patch


Fairy „Ring“, Hedge-like belt of tall long-living grasses
Luxury belt, Perennial belt


Small short-lived grasses
= Matrix vegetation

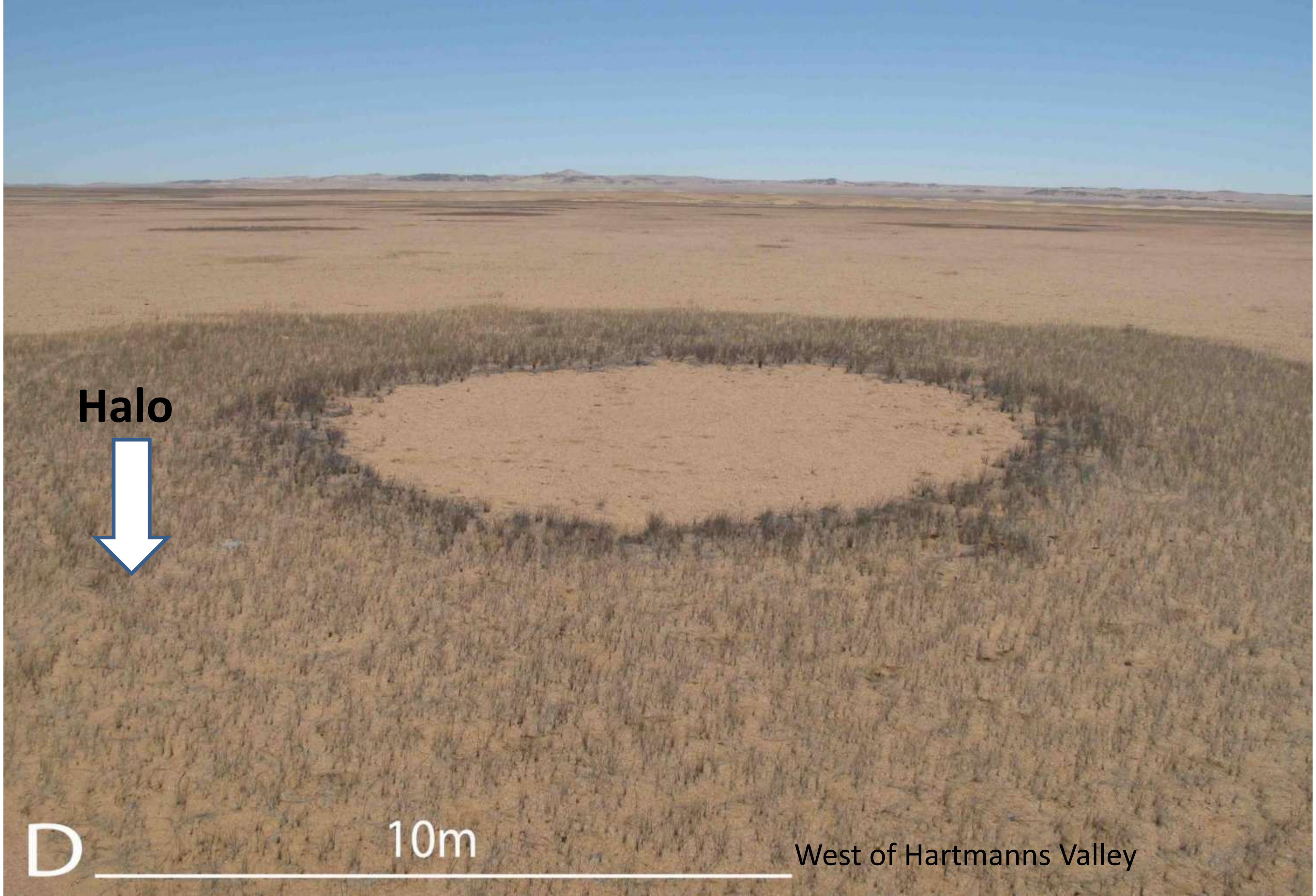

Tall bushman-grass (Stipagrostis ciliata)
All plants recruiting from seed*
*Kappel et al. (2020) Communications Biology

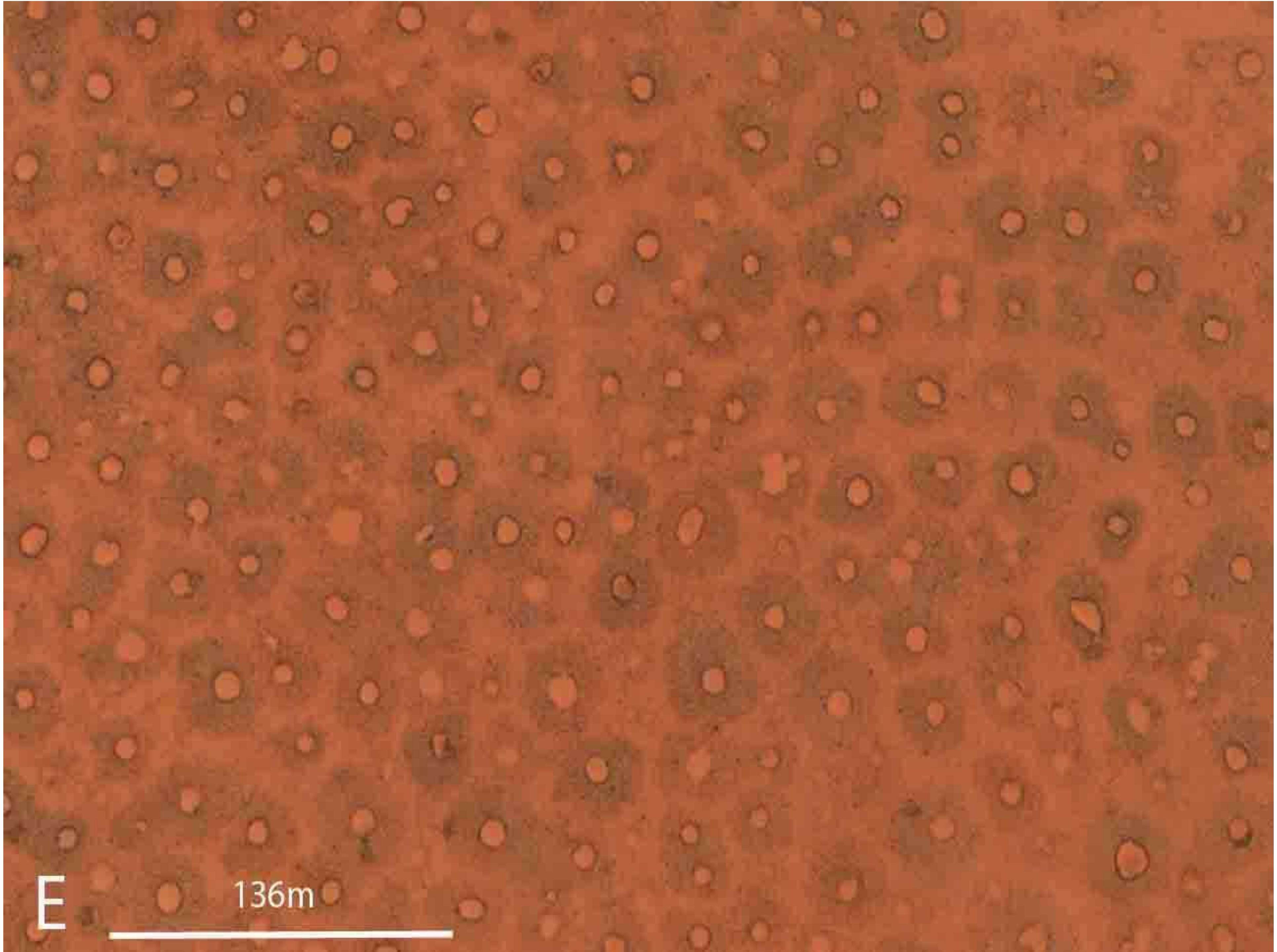

0,5m
Perennial belt (PB)
Perennial belt (PB)
Halo (HA)
Halo (HA)
Matrix (MT)
Matrix (MT)
Ephemeral belt (EB)
Ephemeral belt (EB)
Bare patch (BP)
Stored rain water
1m

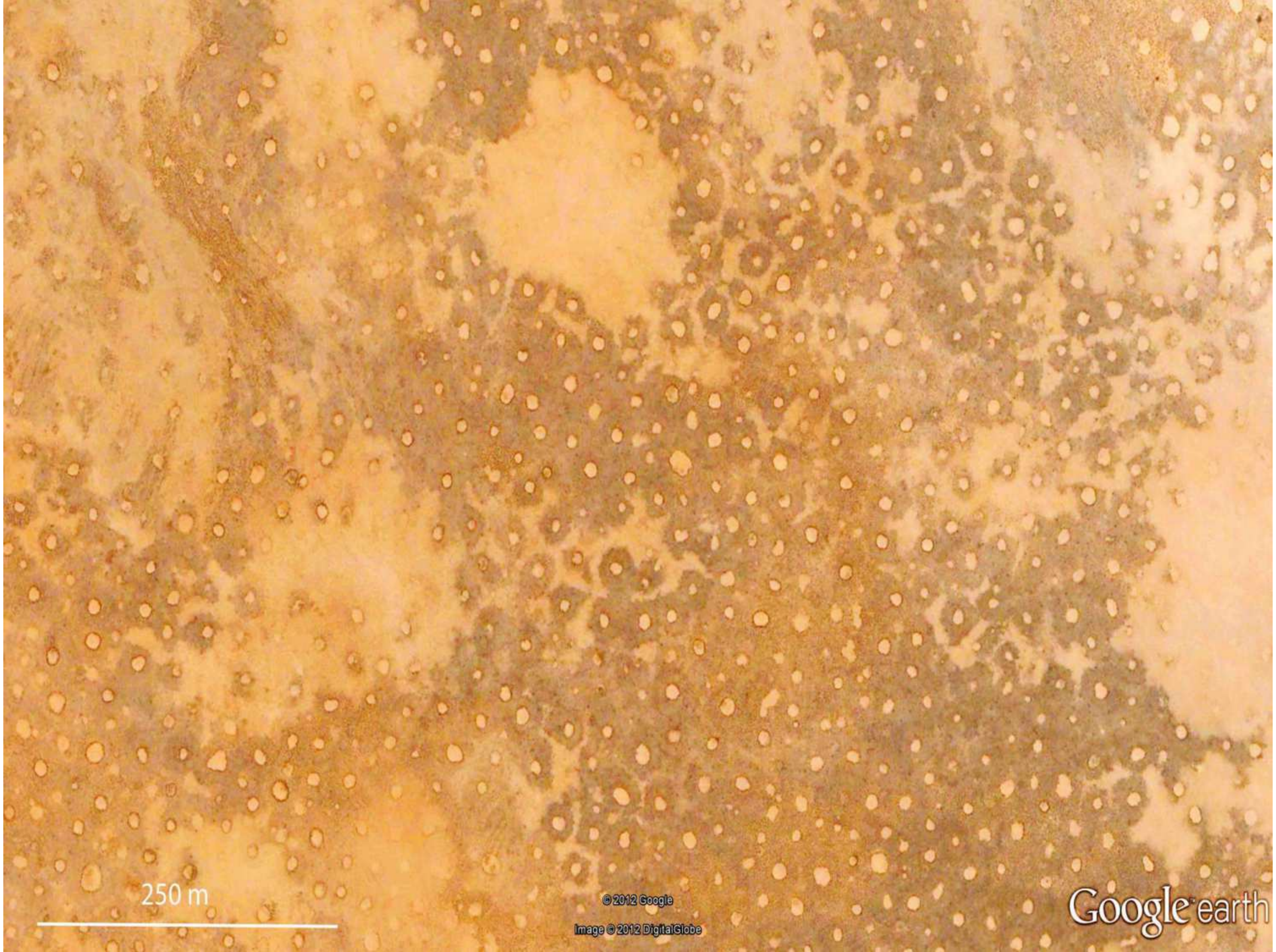

A
10m

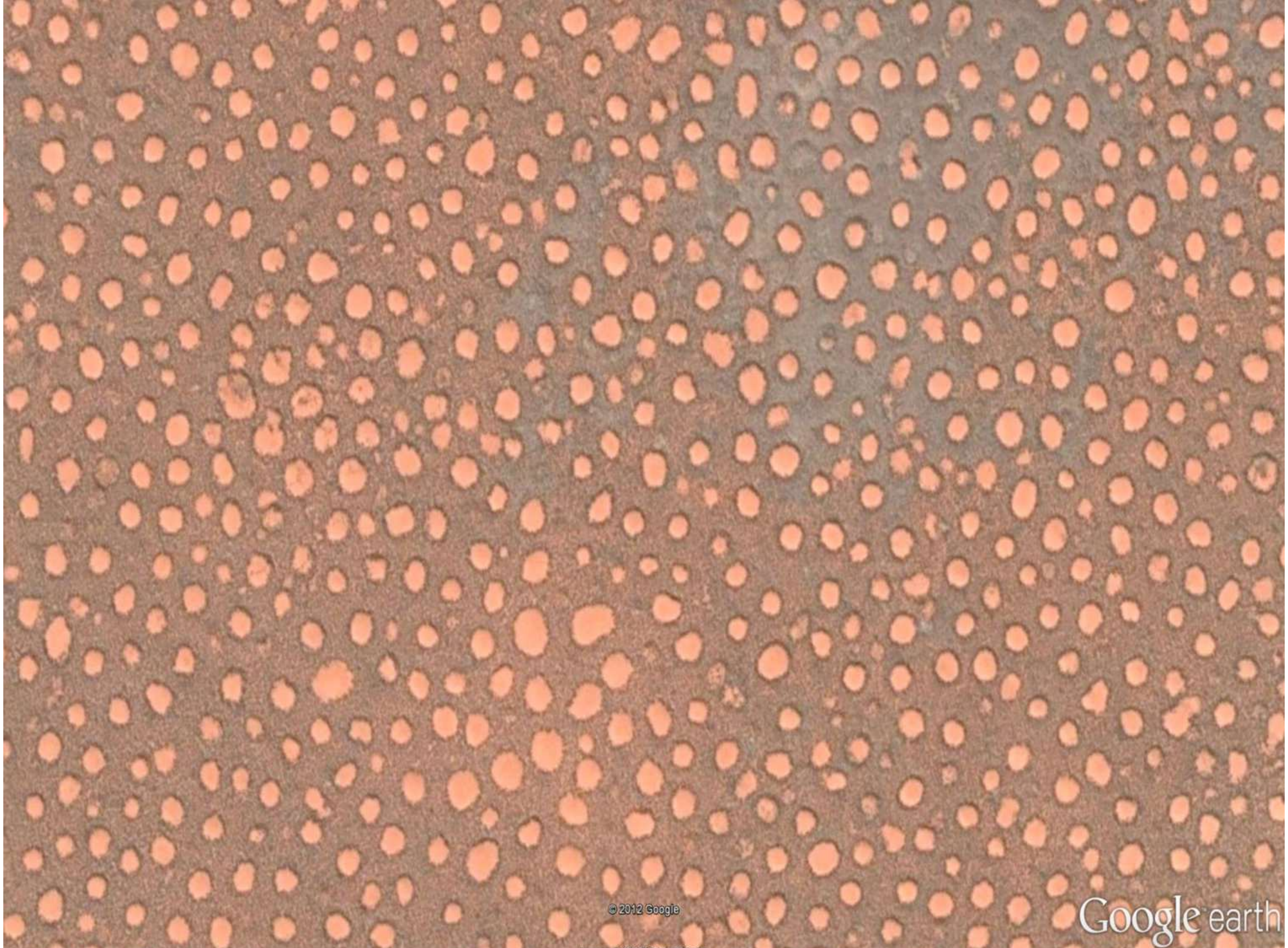

A
10m

Halos: Best developed in the north




E
136m


250 m
© 2012 Google
Image © 2012 DigitalGlobe
Google earth


© 2012 Google
Google earth

Desert becomes permanent grassland, allowing permanent presence of a rich Biodiversity (chapter 8)

Question 4: Is it possible to identify one organism that creates the Namib fairy circles?

Discovery No. 3: 2013

Jürgens (2013): The southern African sand termite (Psammotermes allocerus) is the only organism that occurs in all fairy circle landscapes of the Namib (Science 2013)

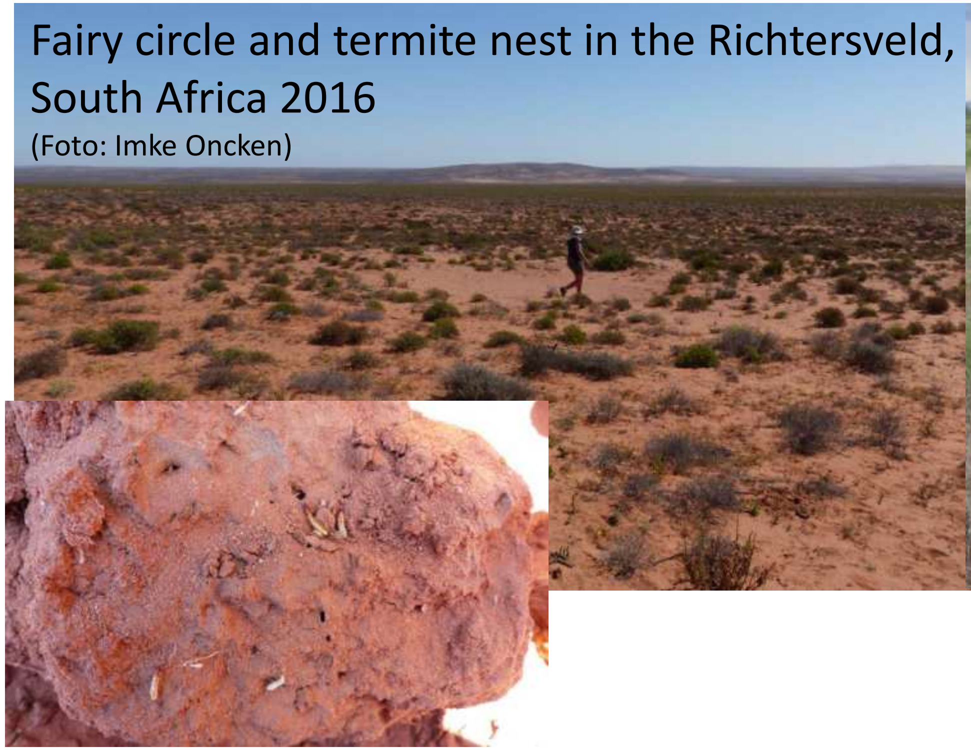
Sand termites - Psammotermes

Felicitas Gunter, PhD – Student, lab manager

Since 2015, I did field work each year in Namibia, South Africa, and Angola in summer and winter times to collect termites in fairy circles of these countries, and to study them morphologically and molecularly.

Main topics: Genetic diversity, Population genetic, Phylogeography, Morphology

Termite species: *Psammotermes allocerus*, species of the family Hodotermitdae



Fairy circle and termite nest in the Richtersveld, South Africa 2016

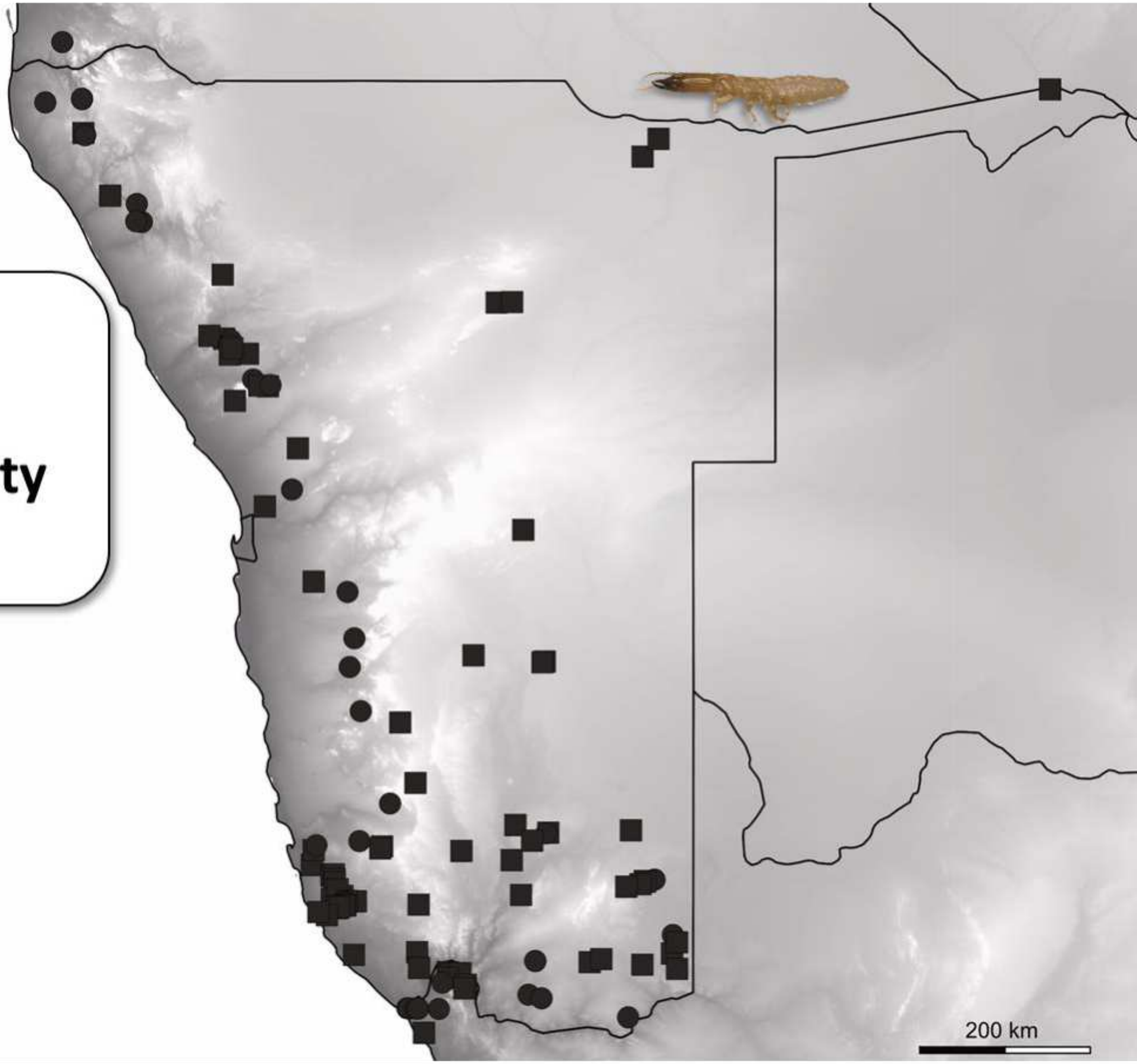
(Foto: Imke Oncken)

Fairy circle in Marienfluss Valley, Namibia 2017

Fairy circle and termite nest in Iona National Park, Angola 2018

Diversification of the sand termite *Psammotermes allocerus*

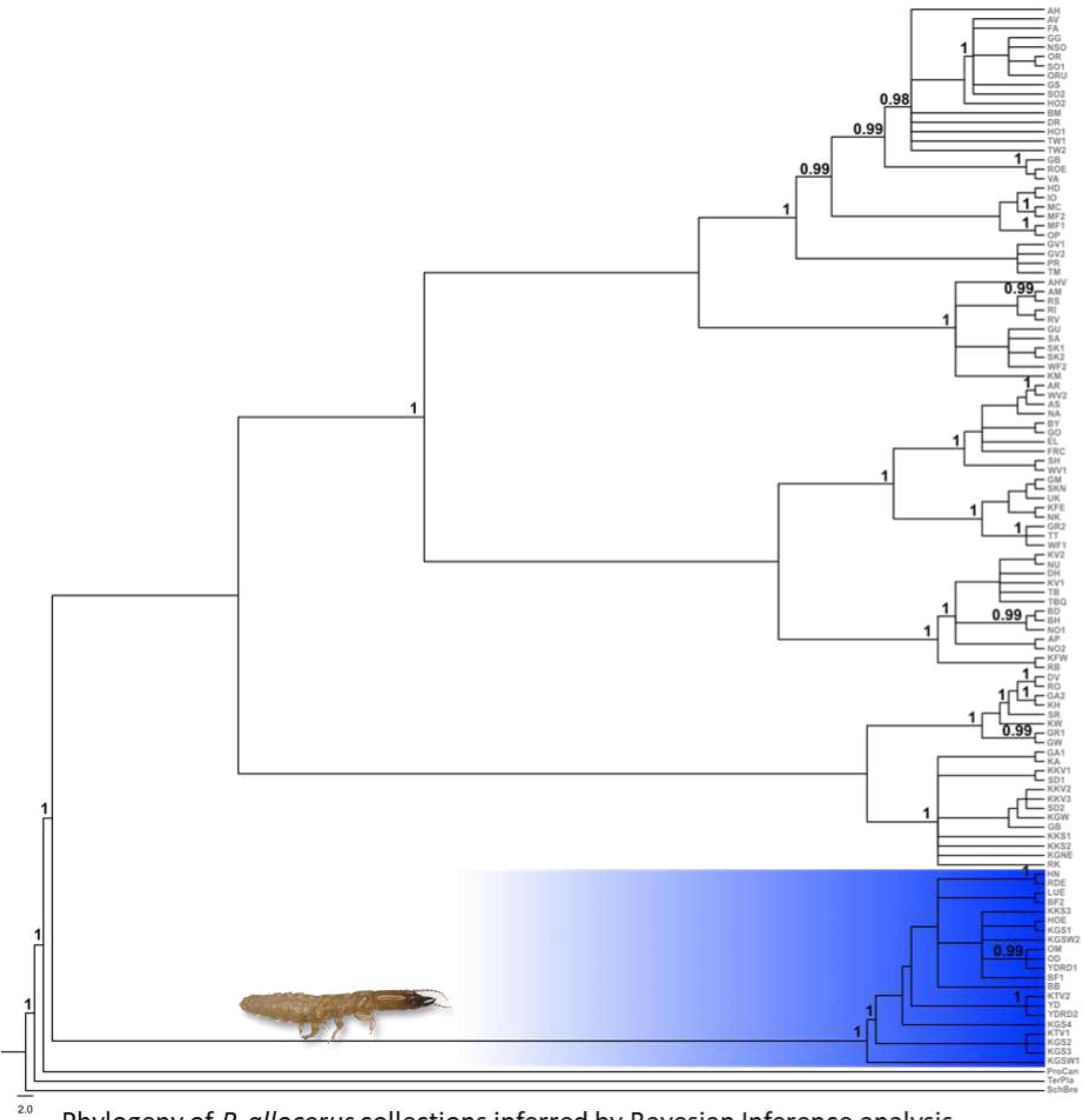
Based on **113 collections** of the sand termite from **Angola, Namibia** and **South Africa**, we were able to determine a high **genetic diversity** using barcode marker (COI and COII)



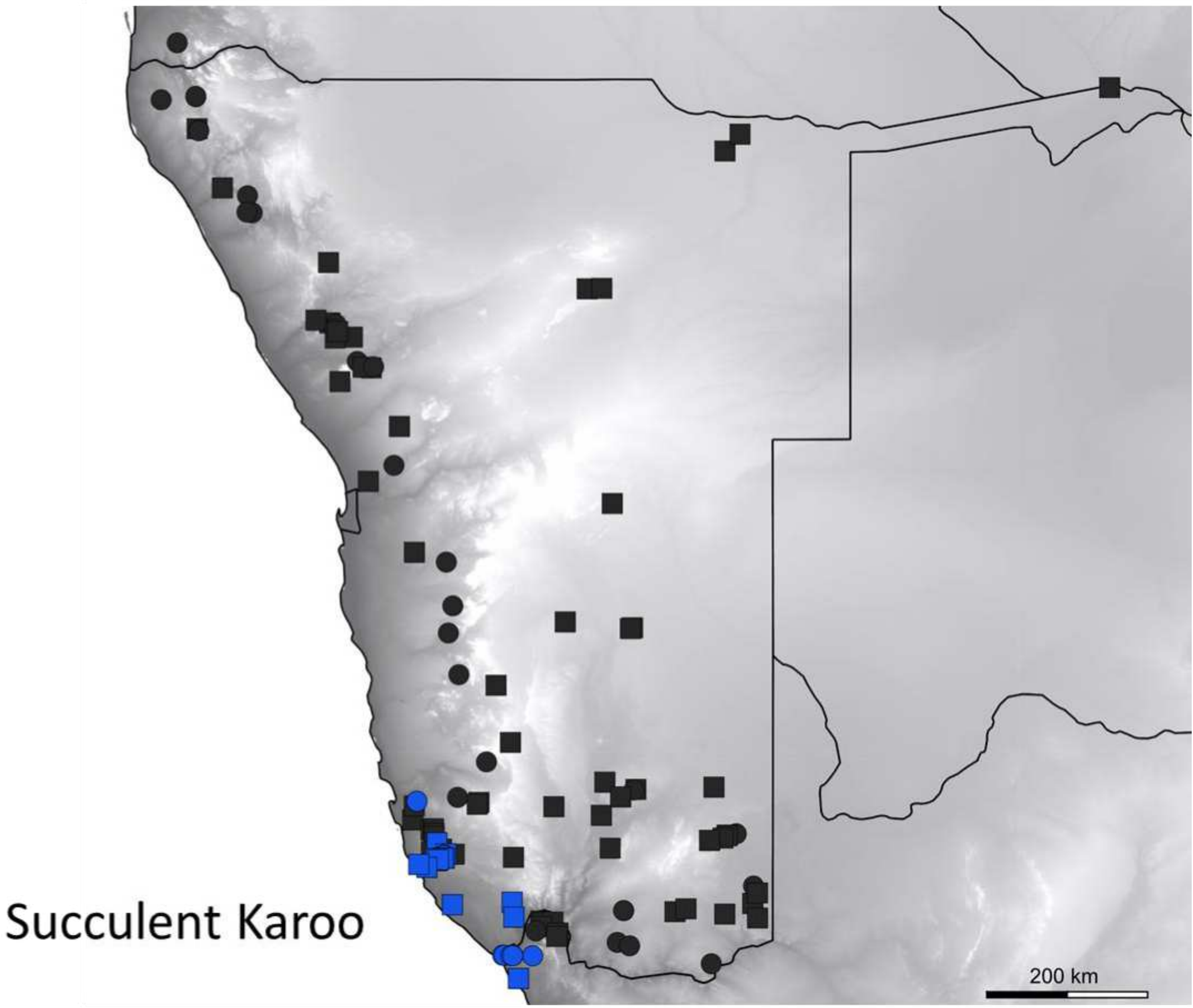
Distribution map of *P. allocerus* collections

Gunter et al. (2022) Phylogeny of sand termites - in: Schmiedel & Finckh (Eds.) Fairy circles of the Namib Desert (2022)

Diversification of the sand termite *Psammotermes allocerus*



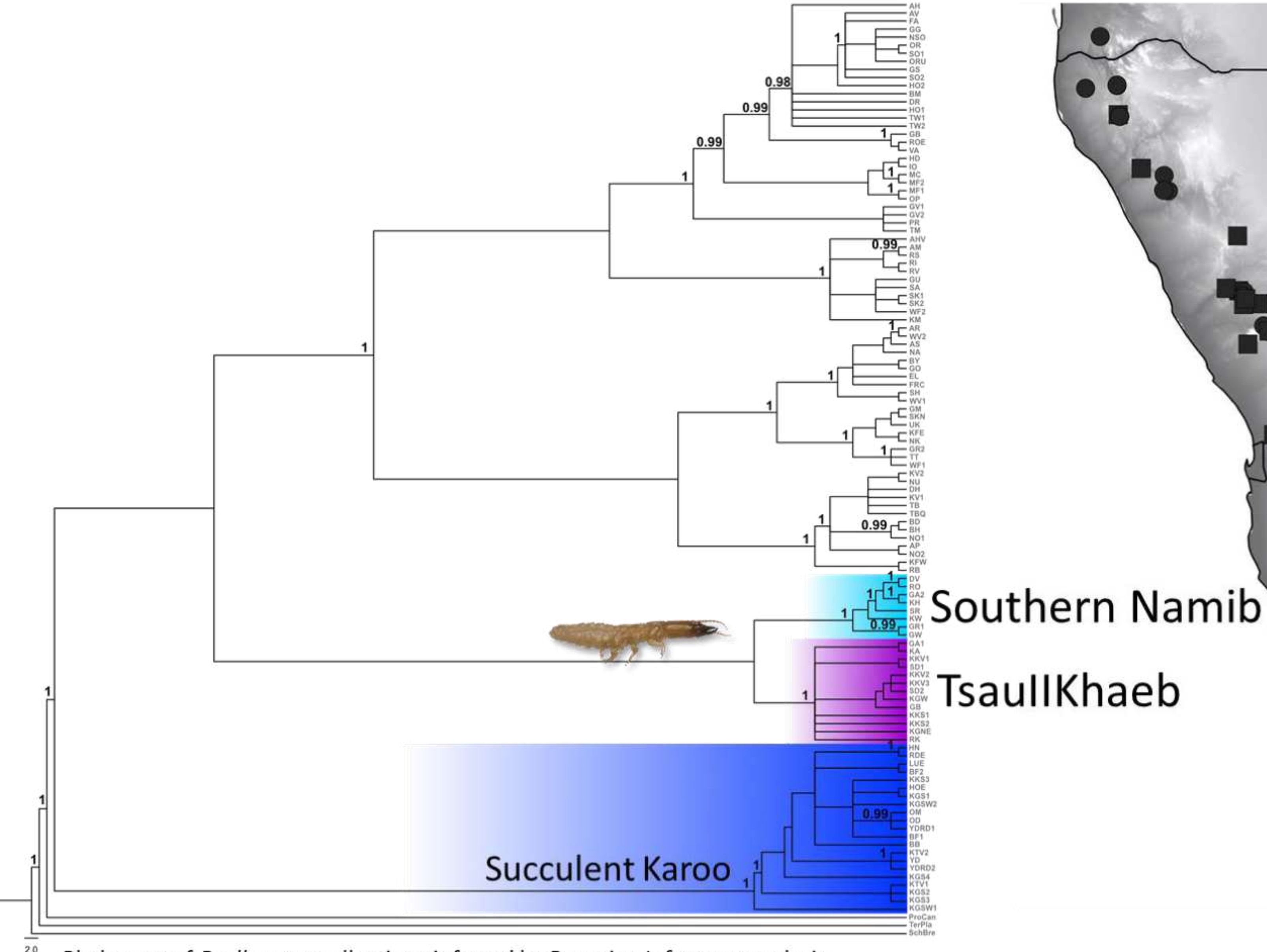
Phylogeny of *P. allocerus* collections inferred by Bayesian Inference analysis



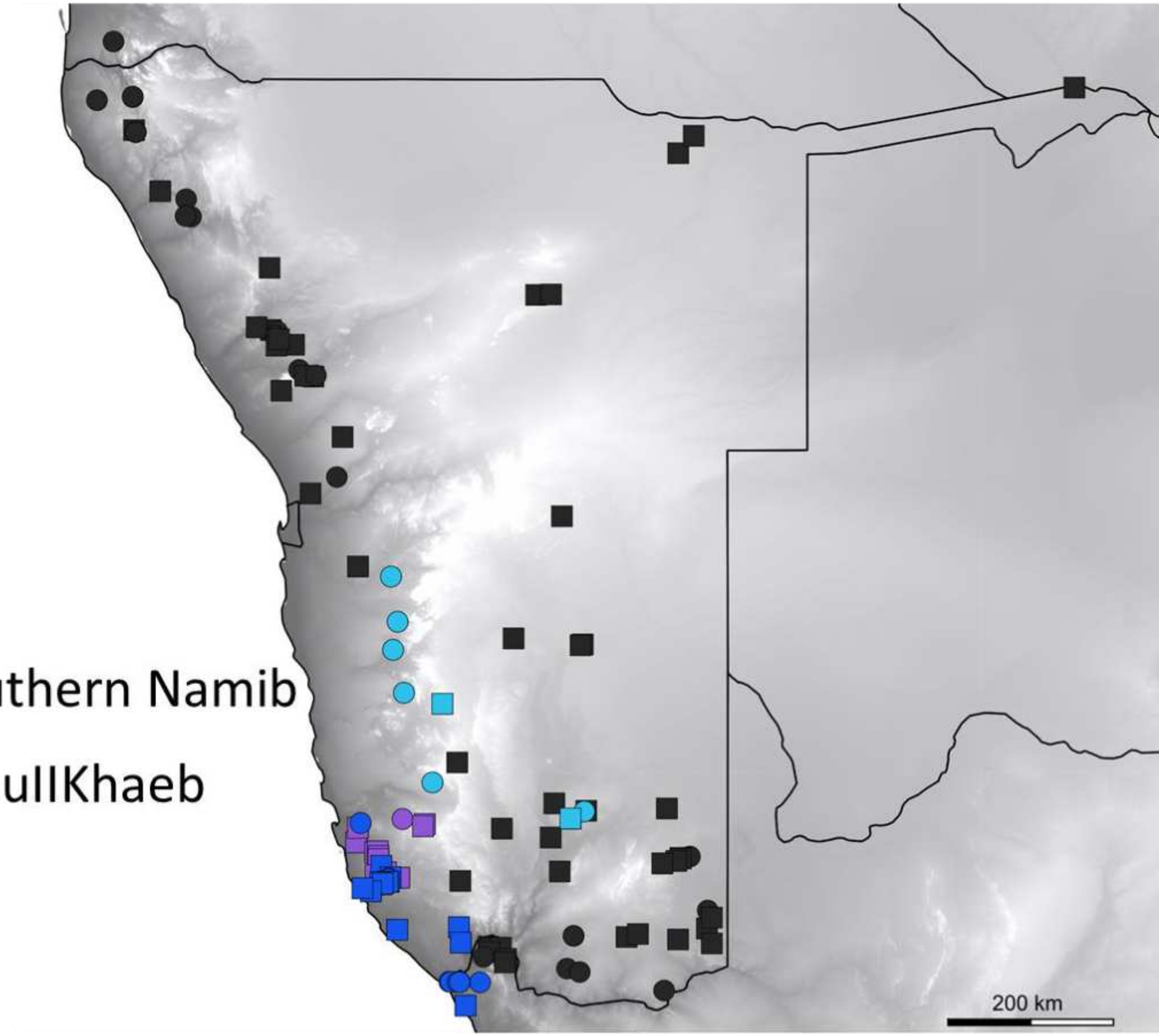
Distribution map of *P. allocerus* collections

Gunter et al. (2022) Phylogeny of sand termites

Diversification of the sand termite *Psammotermes allocerus*



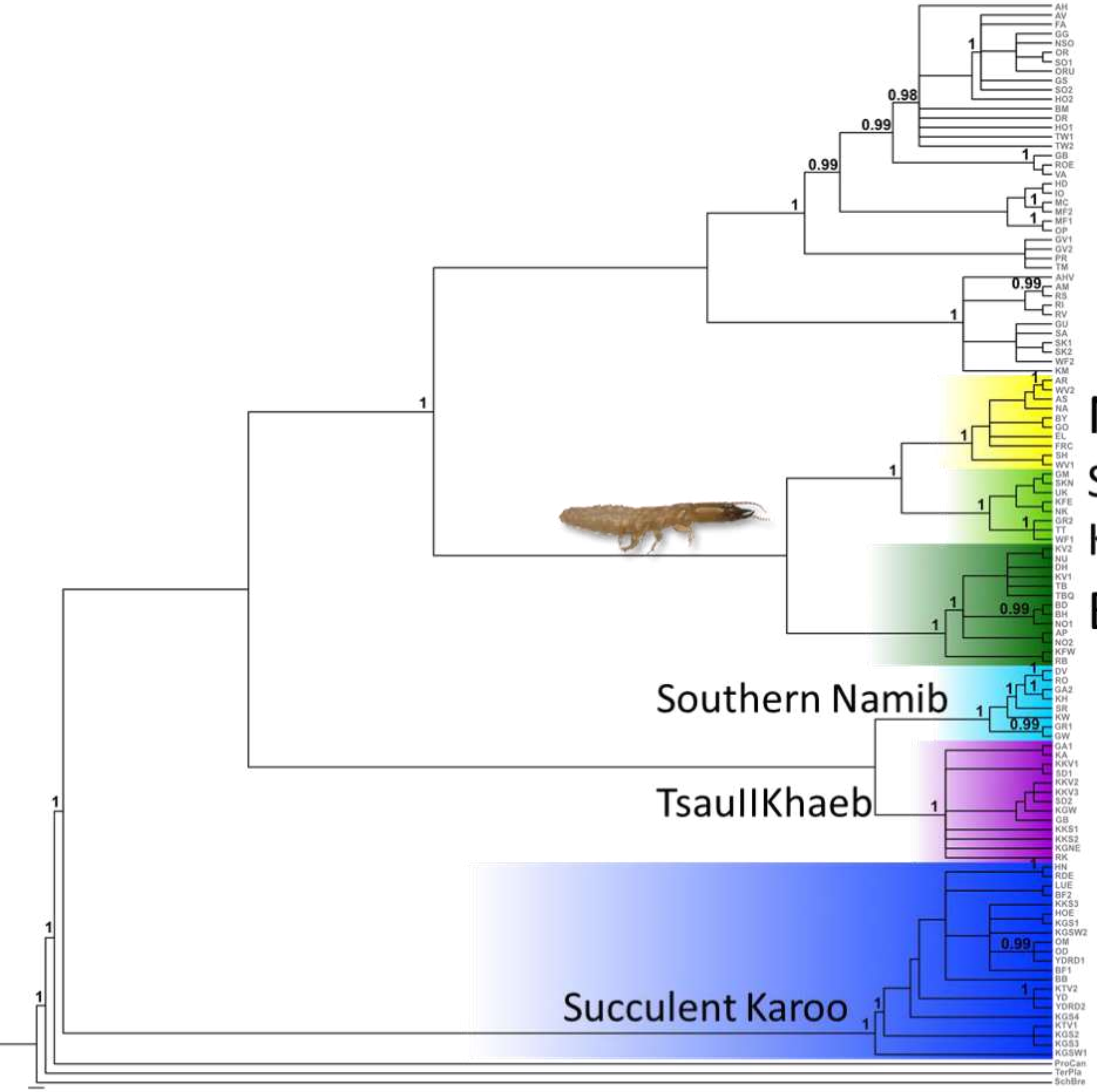
Phylogeny of *P. allocerus* collections inferred by Bayesian Inference analysis



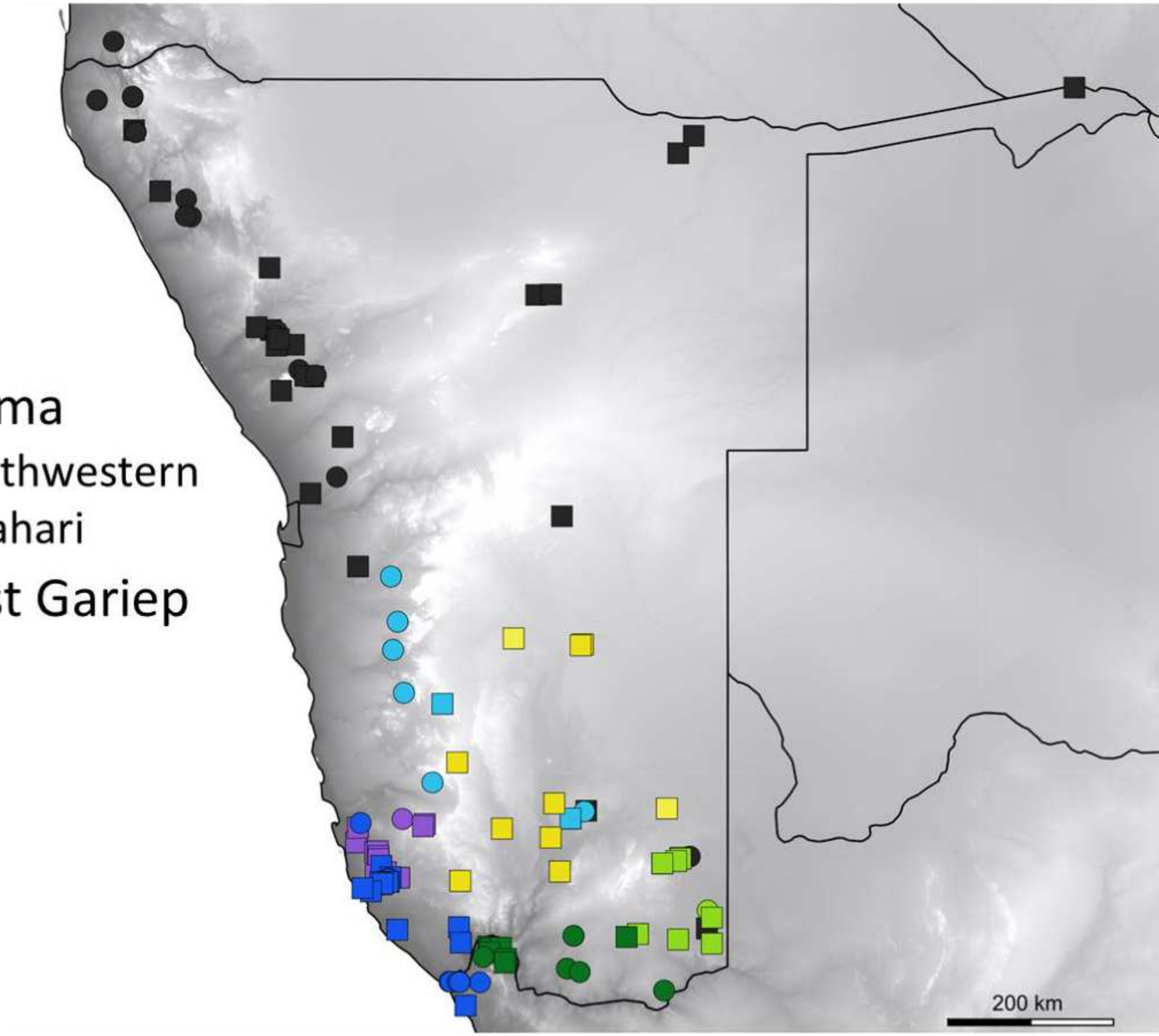
Gunter et al. (2022) Phylogeny of sand termites

Distribution map of *P. allocerus* collections

Diversification of the sand termite *Psammotermes allocerus*



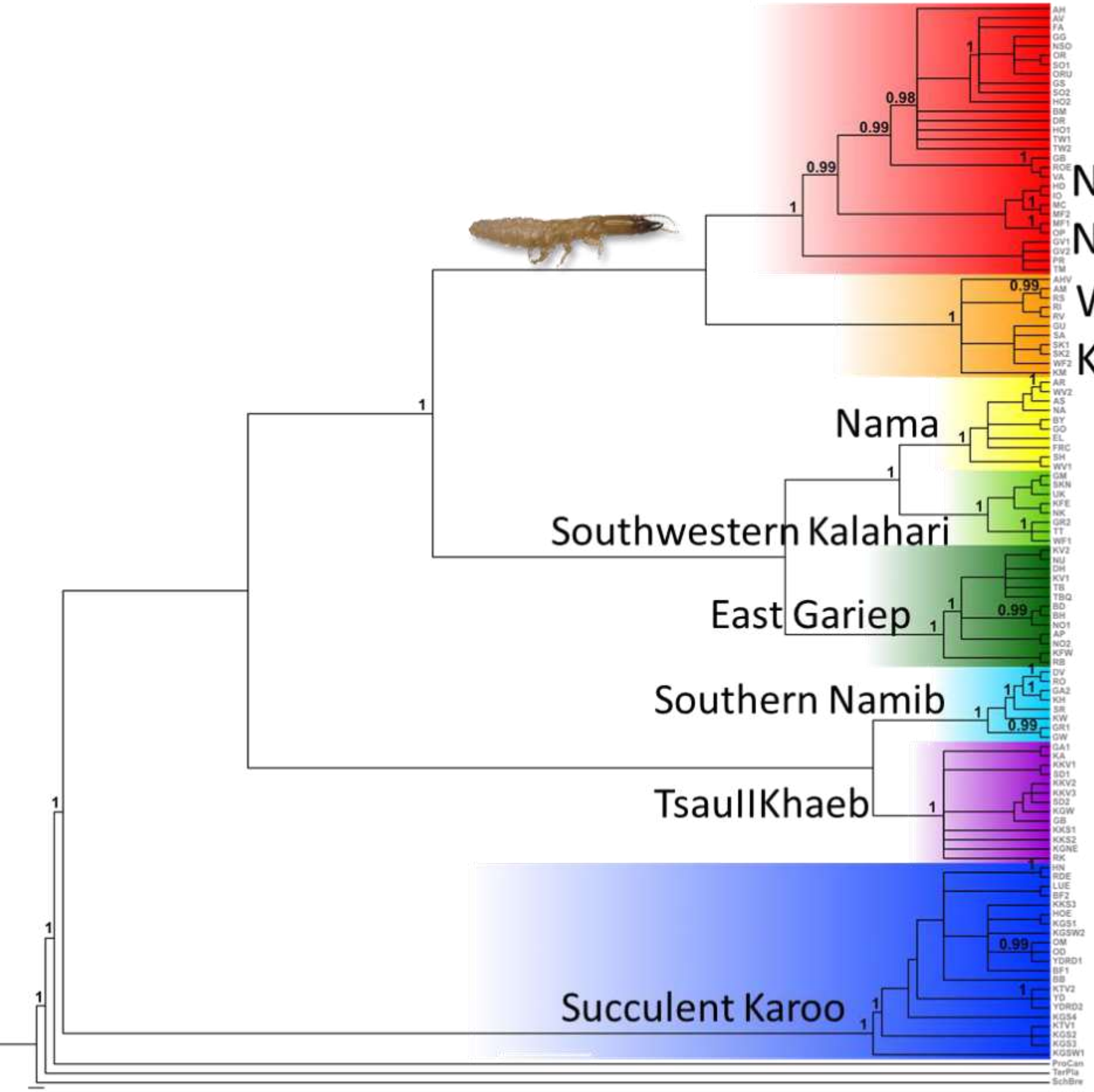
Phylogeny of *P. allocerus* collections inferred by Bayesian Inference analysis



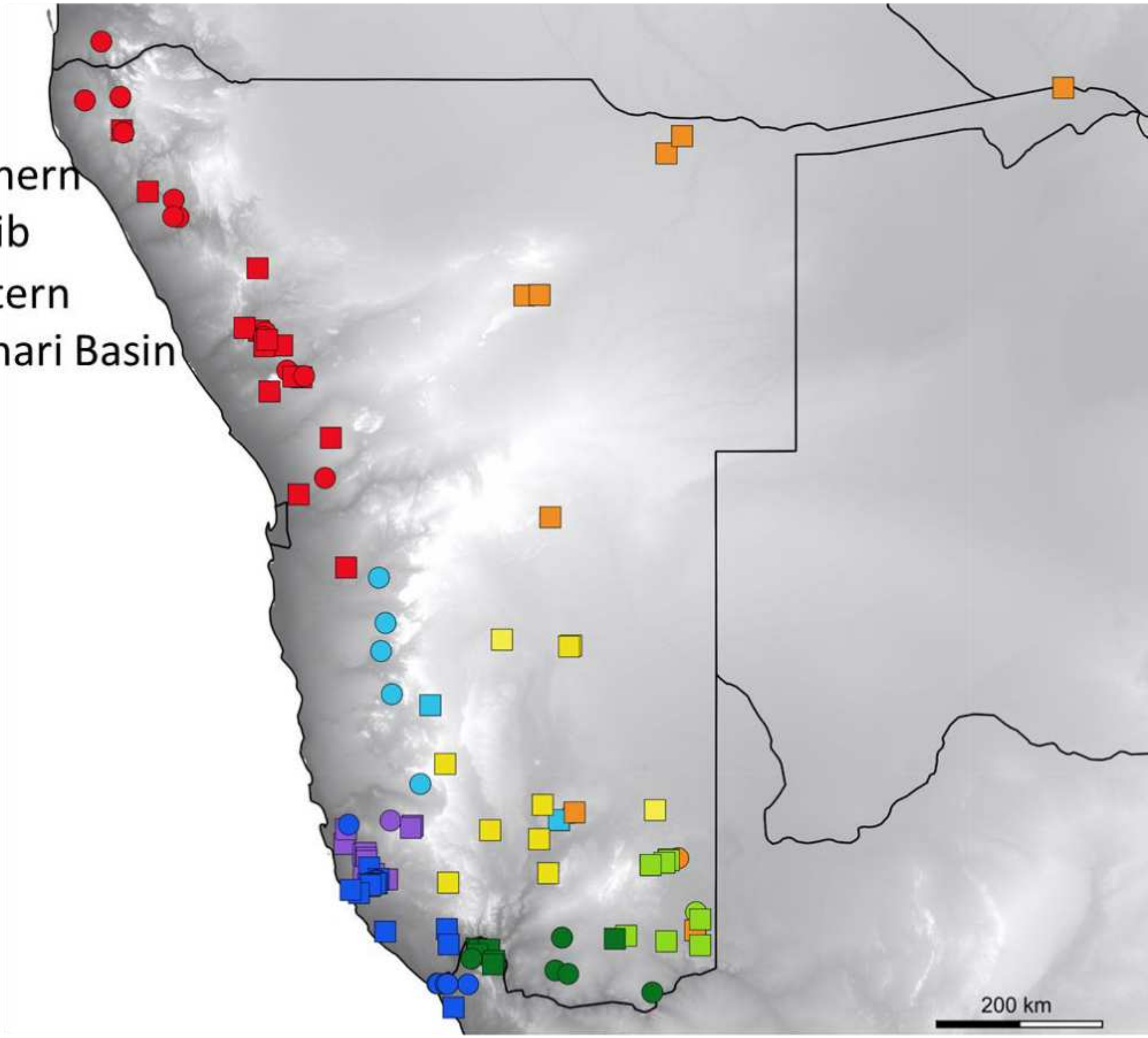
Gunter et al. (2022) Phylogeny of sand termites

Distribution map of *P. allocerus* collections

Diversification of the sand termite *Psammotermes allocerus*



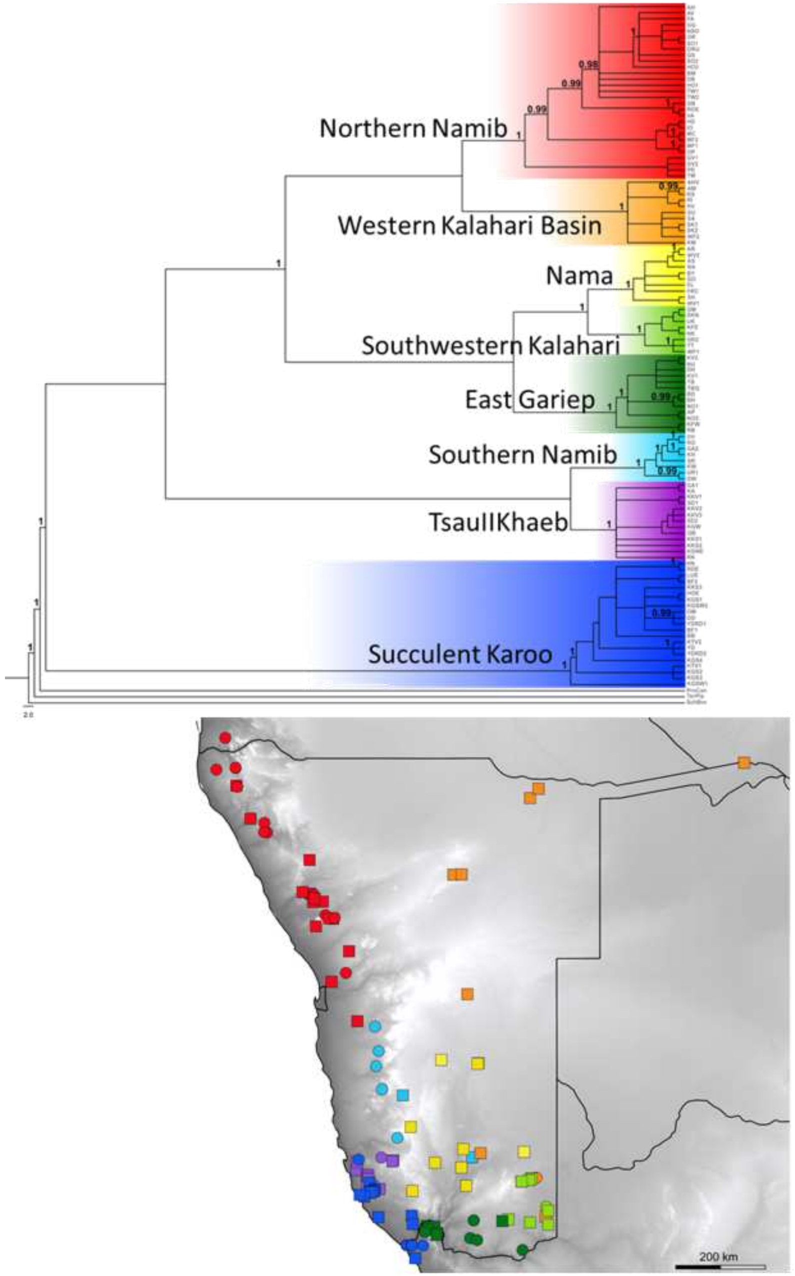
Phylogeny of *P. allocerus* collections inferred by Bayesian Inference analysis



Gunter et al. (2022) Phylogeny of sand termites

Distribution map of *P. allocerus* collections

Diversification of the sand termite *Psammotermes allocerus*



***Psammotermes allocerus* can not be regarded as one single species, but as an aggregate of eight closely related species**

- In future the "Succulent Karoo" group retains the name *Psammotermes allocerus* (due to type specimen from Lüderitz). The other seven species will get seven new *Psammotermes* species names.
- Genetic classification is supported by morphological differences of soldier mandible shape and 25 characters

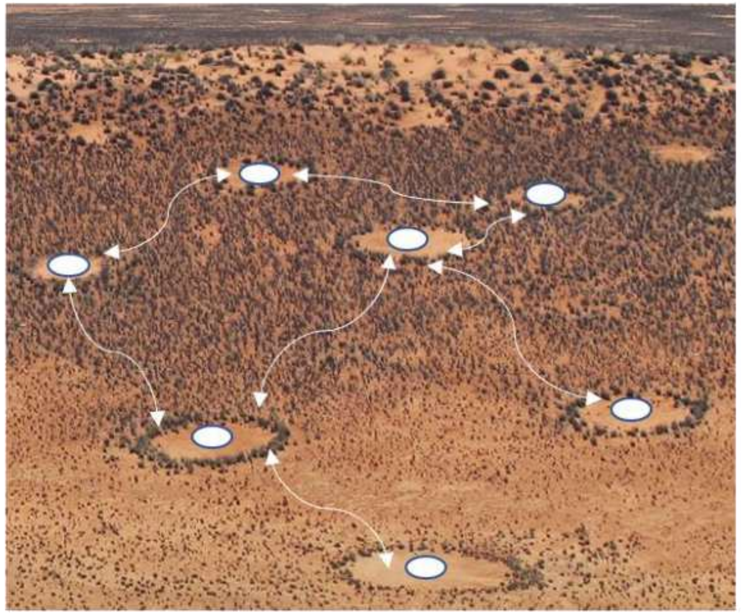
Gunter et al. (2022) Phylogeny of sand termites - in: Schmiedel & Finckh (Eds.) Fairy circles of the Namib Desert (2022)

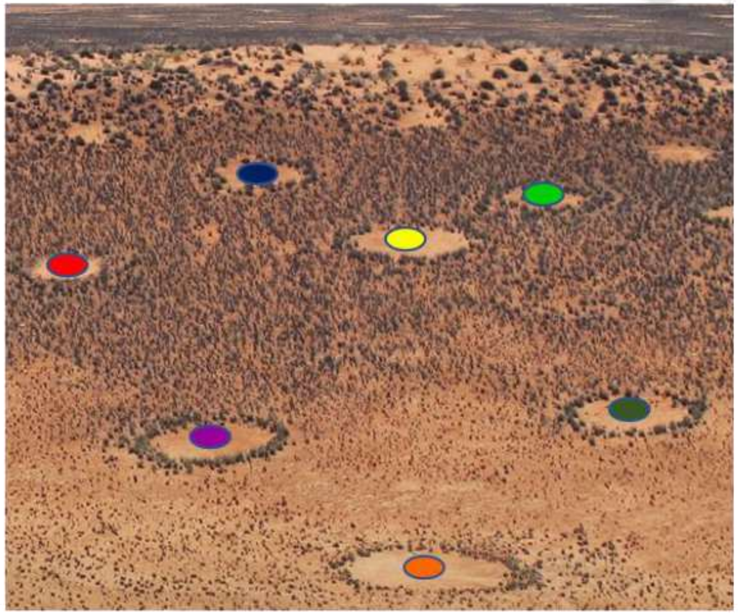
Population genetic of the sand termite *Psammotermes allocerus*

Hypothesis 1
Each fairy circle is inhabited by a sand termite colony that migrated directly from a neighboring fairy circle.

OR

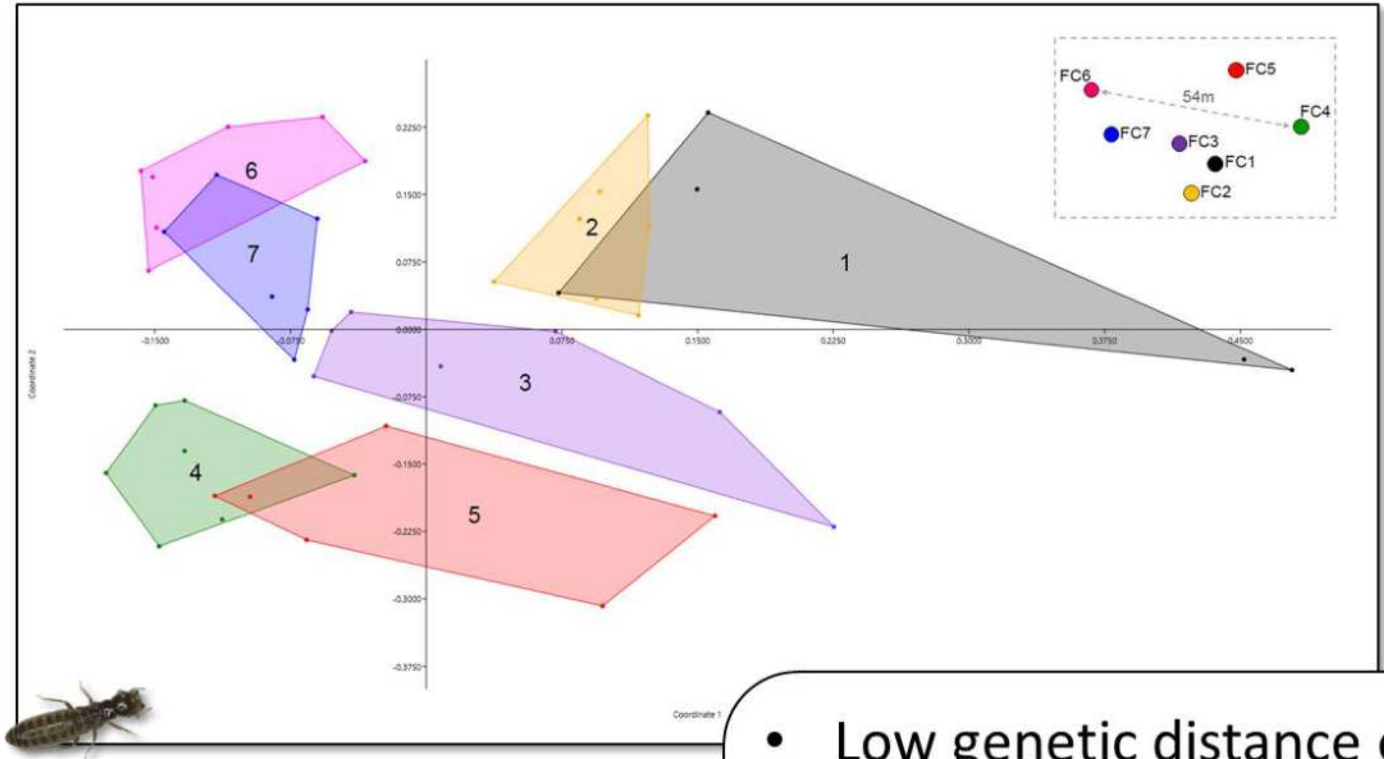
Hypothesis 2
Each fairy circle is founded by a new queen and king from further away.



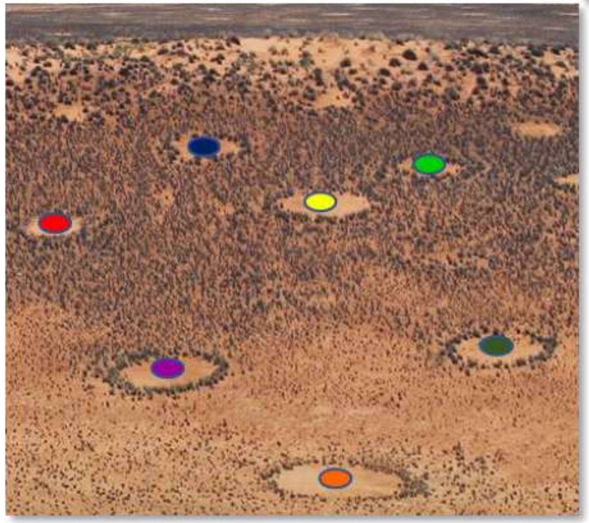


Gunter et al. (2022) Reproduction of sand termites and local genetic patterns - in: Schmiedel & Finckh (Eds.) Fairy circles of the Namib Desert (2022)

Population genetic of the sand termite *Psammotermes allocerus*



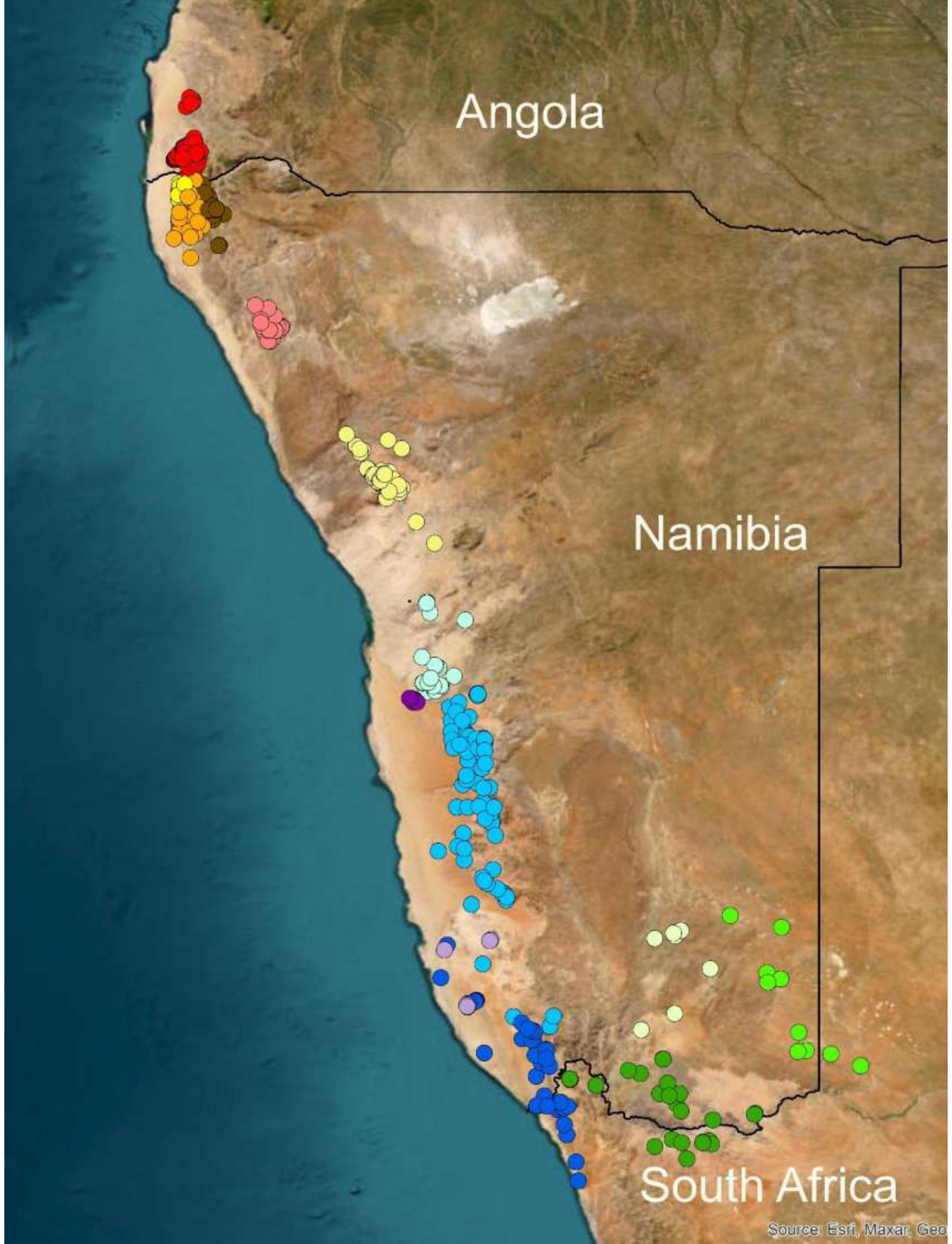
Principal Coordinate Analysis (PCoA)
of sand termites from Dieprivier („Southern Namib“)
generated from AFLP data.



- Low genetic distance of termites from one colony and FC
- High genetic dissimilarity among termites of neighboring FCs

➢ Each fairy circle is inhabited by one *P. allocerus* colony
➢ Fairy circles are founded from a new queen from far away

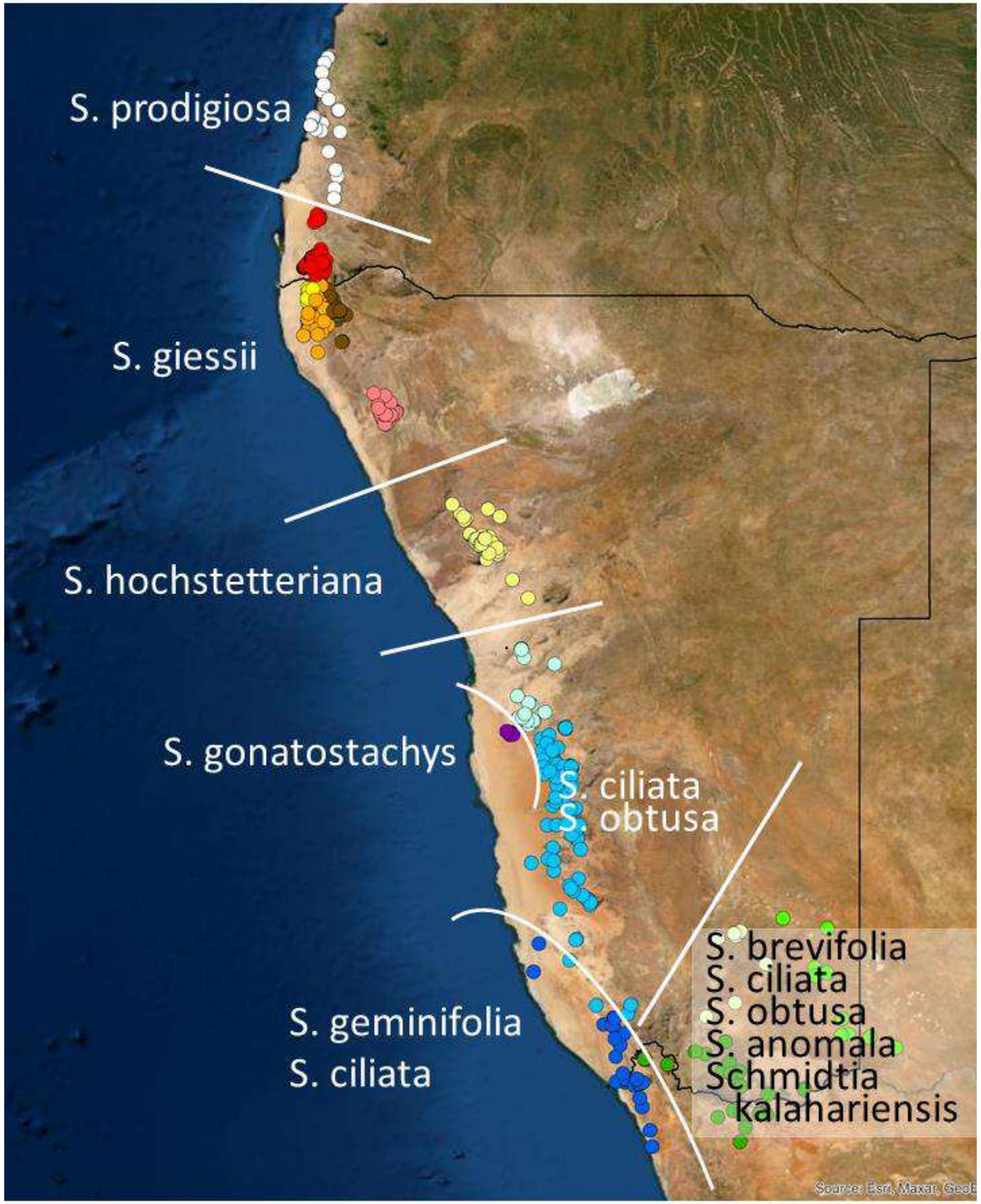
Gunter et al. (2022) Reproduction of sand termites and local genetic patterns- in: Schmiedel & Finckh (Eds.) Fairy circles of the Namib Desert (2022)



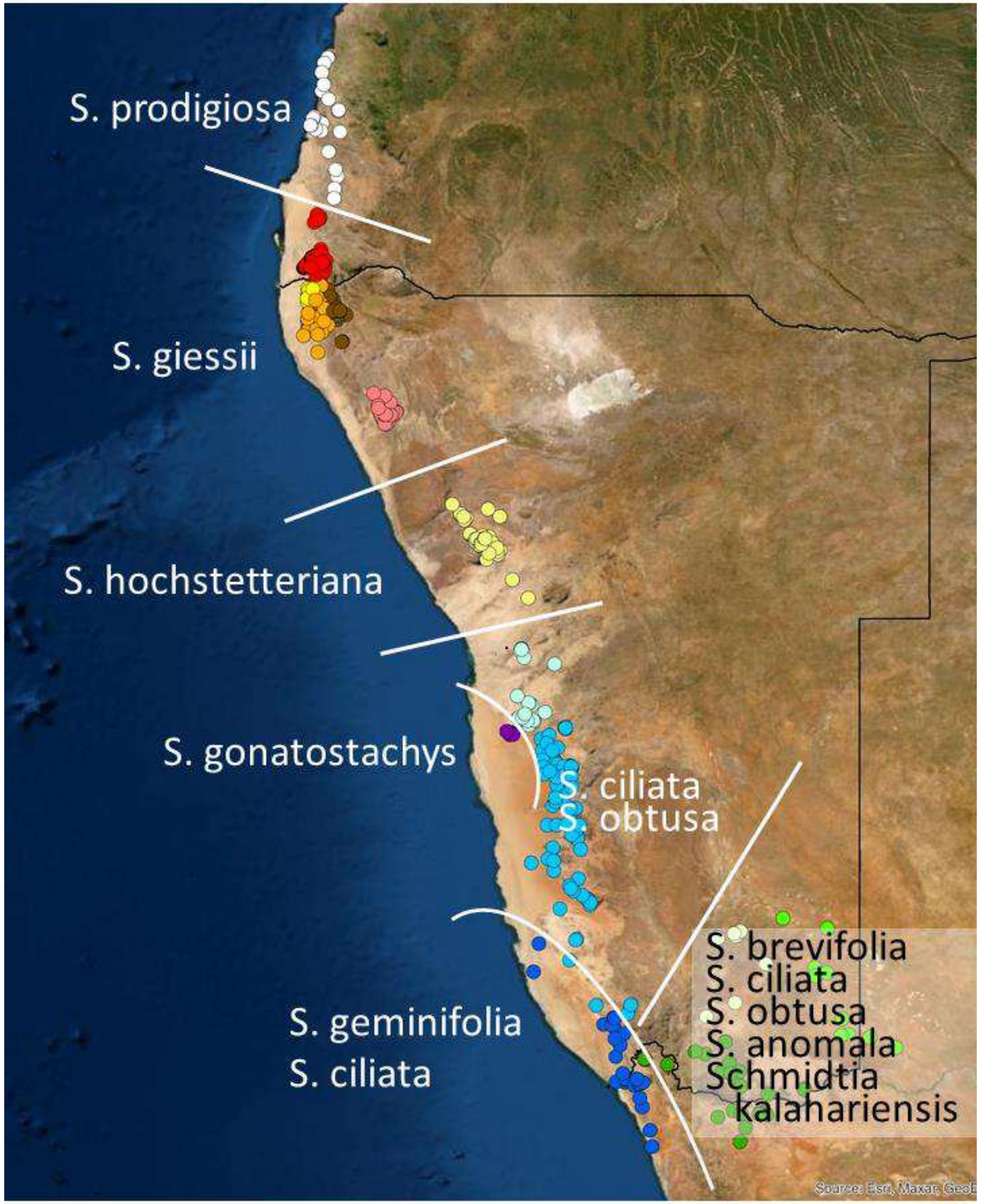
This map is based on 1.799 Fairy Circles with documented presence of sand termites !!!!

Sand termite fairy circles in Angola: Iona National Park, S of Espinheira

Sand termite fairy circles in Angola: Iona National Park, btwn Espinheira and Foz de Cunene



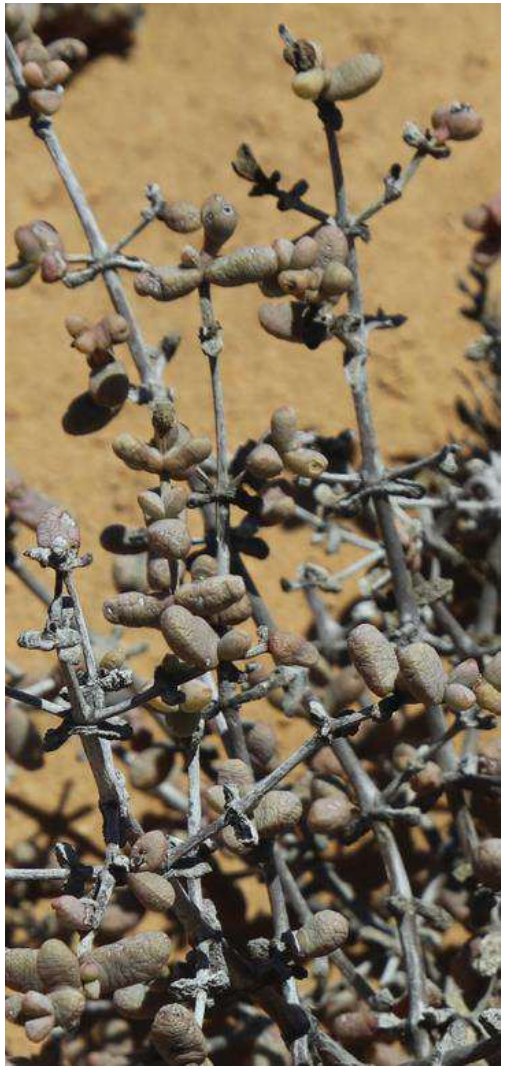
Dominant grass species



Succulent Karoo: Mainly woody dwarf shrubs

Brownanthus arenosus
Cheiridopsis brownii
Sarcocaulon patersonii
Eberlanzia sedoides
Brownanthus pseudo-schlichtianus
Chlorophytum viscosum
Othonna cylindrica
Othonna sedifolia
…

Grasses lower relevance, often missing

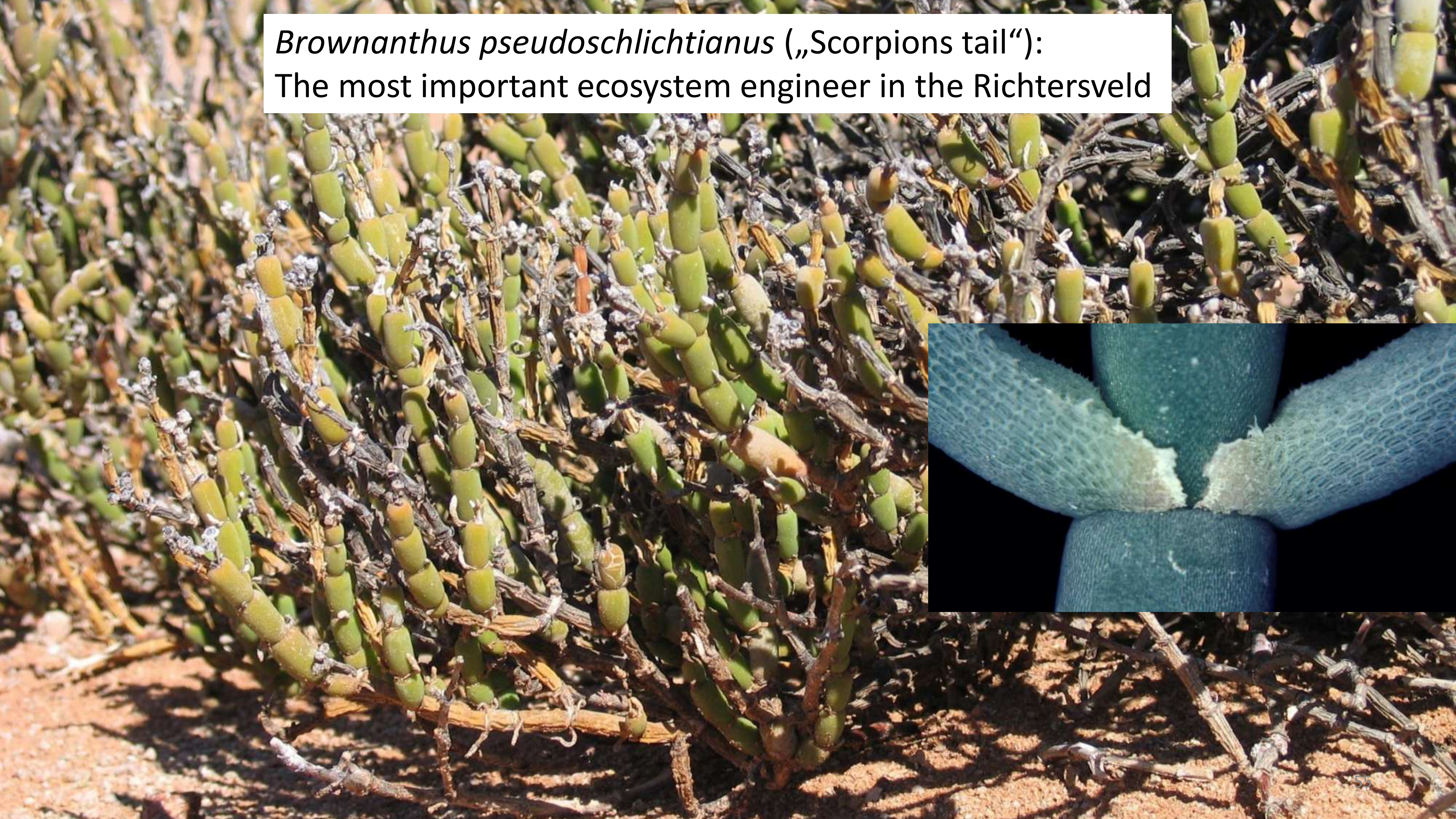


Sand termite fairy circles in South Africa: Btwn Alexander Bay and Yellow Dune Observatory

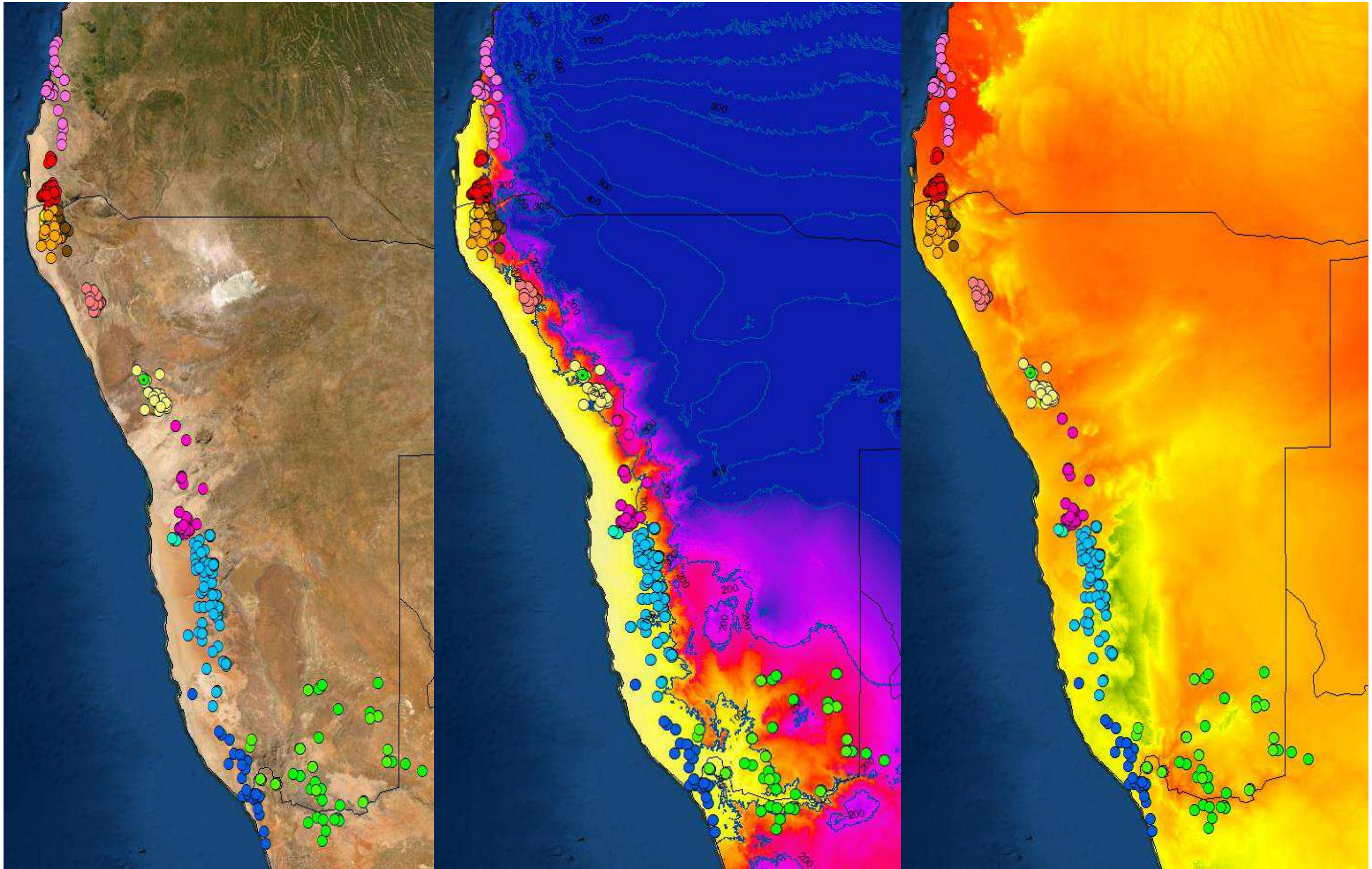

Cheiridopsis brownii
Xanthoparmelia walteri

Sand termite fairy circles in South Africa: Btwn Alexander Bay and Yellow Dune Observatory

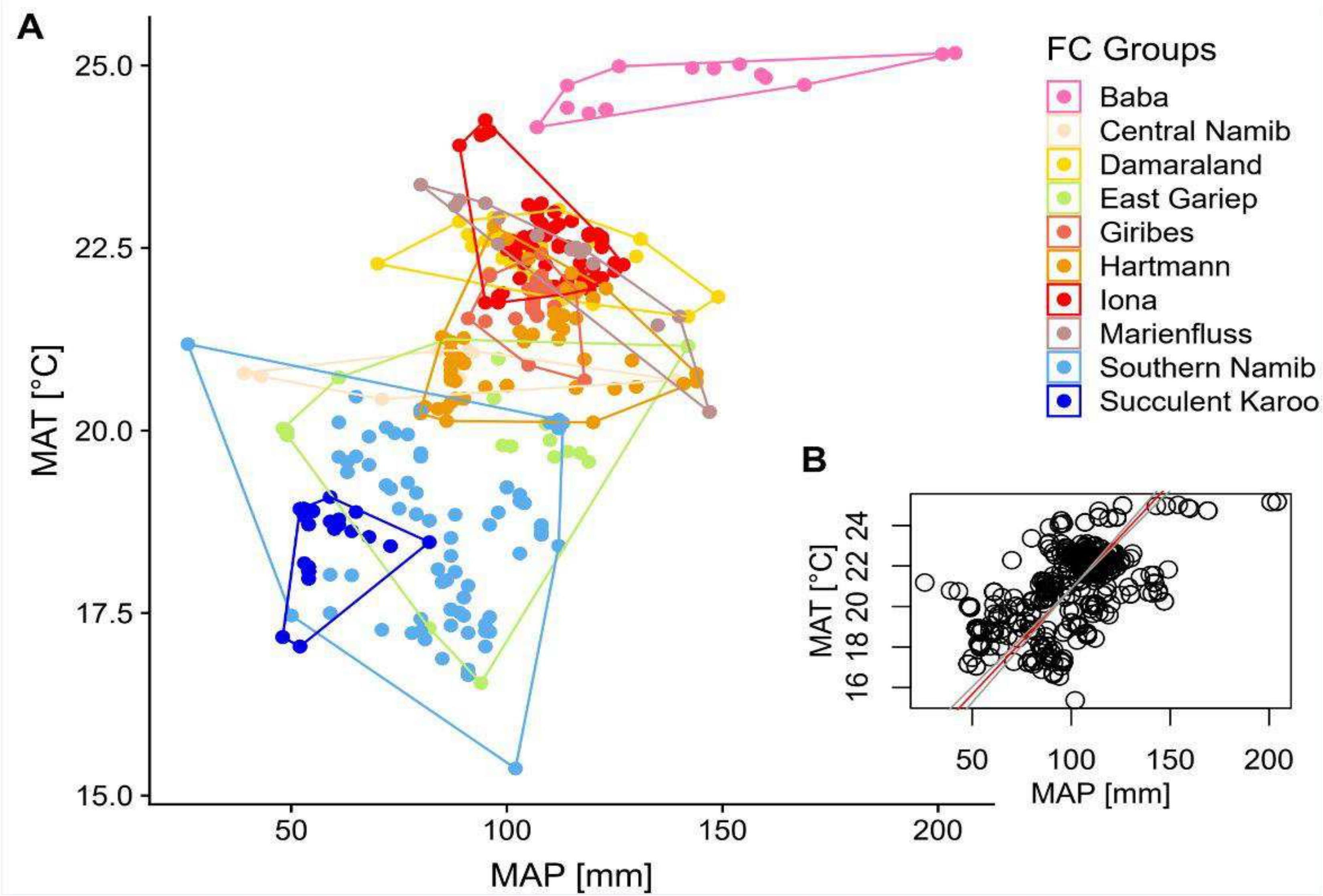
Brownanthus pseudoschlichtianus („Scorpions tail“):
The most important ecosystem engineer in the Richtersveld



Topo MAP MAT



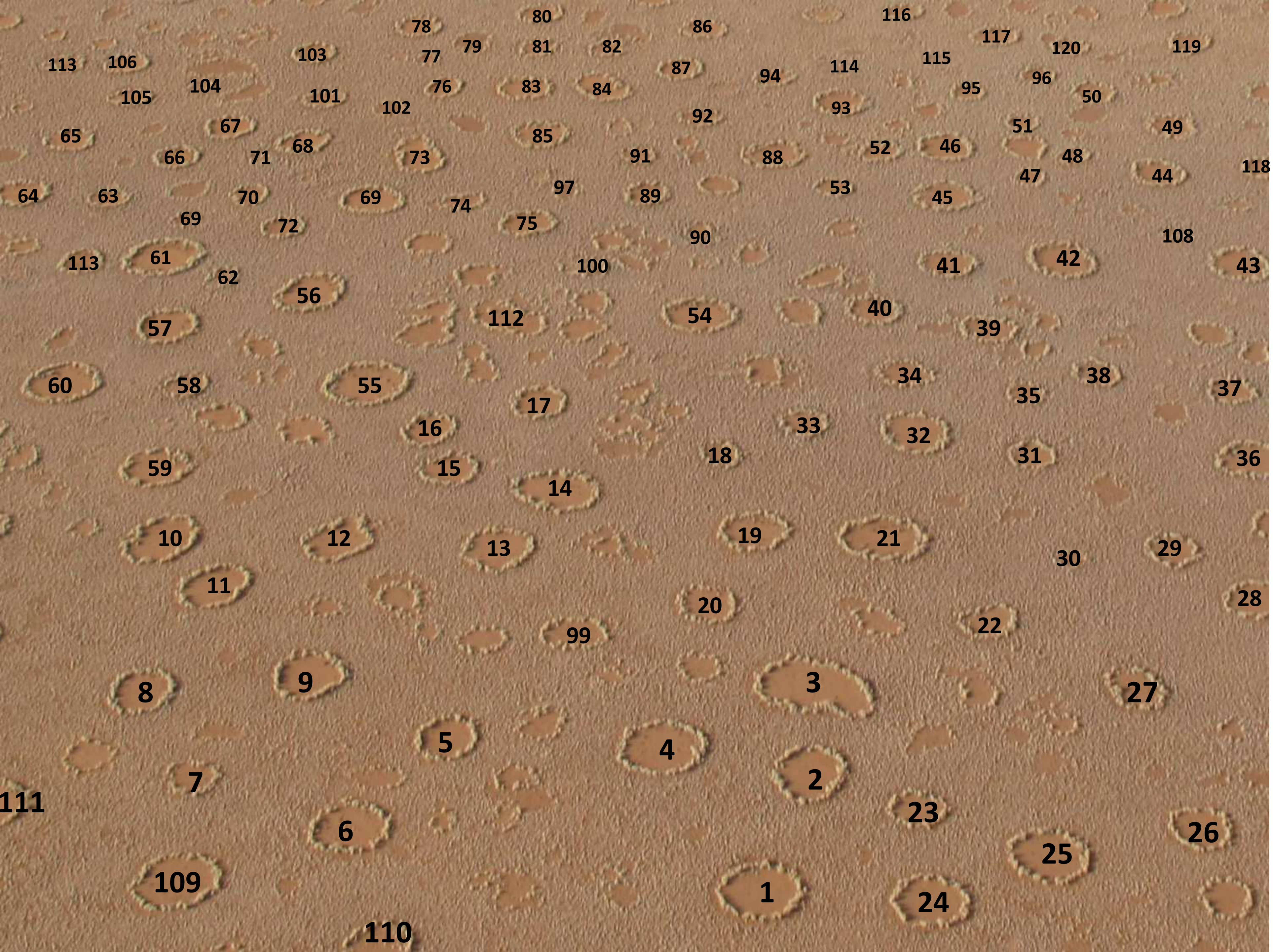
Fairy circles and climate (n >1700)



Question 5: Do sand termites posses biological abilities that allow the to create and maintain fairy circles? Do these fit to the processes of formation, maintenance and death of fairy circles?

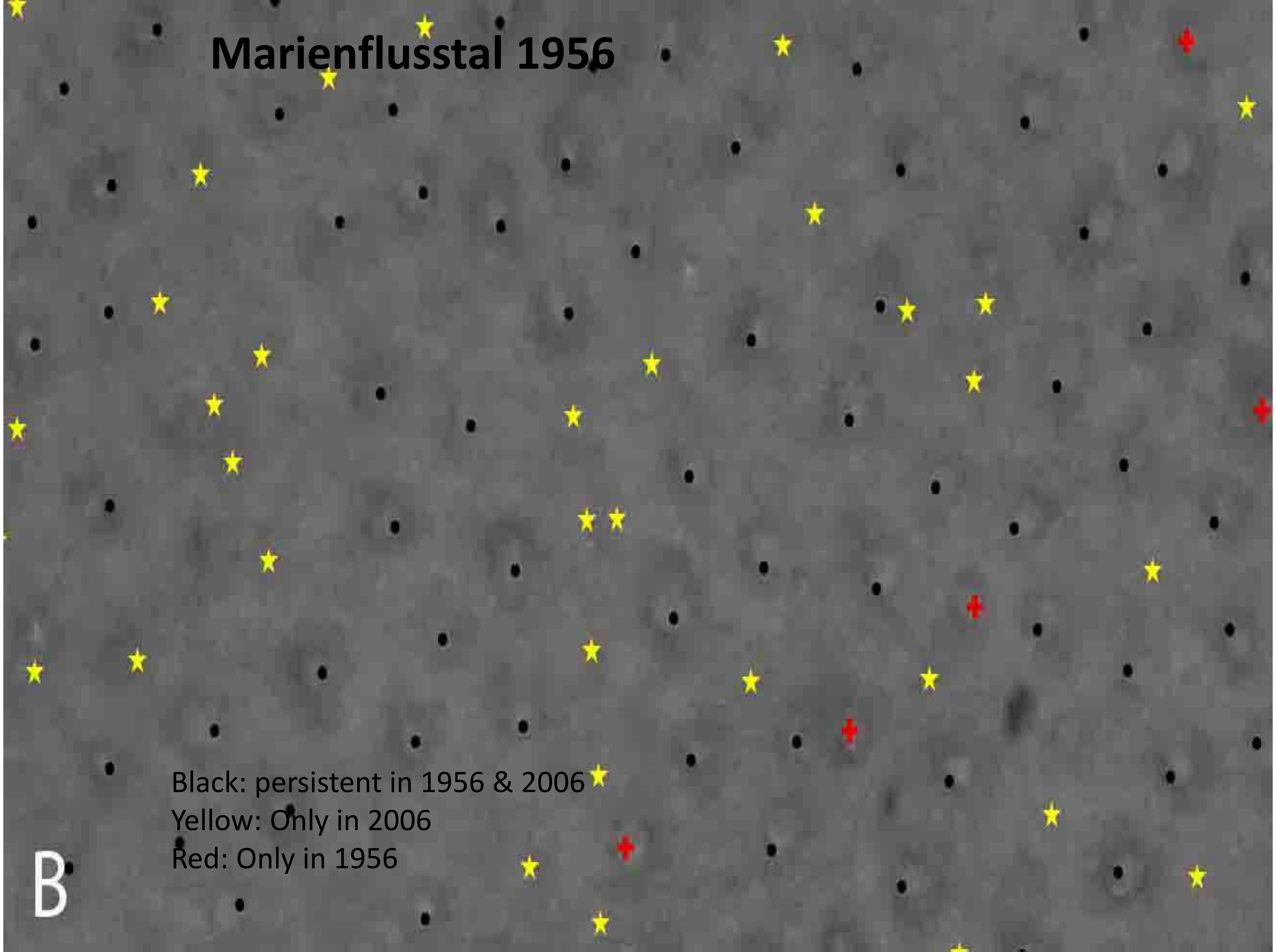
Psammotermes allocerus

Psammotermes allocerus
“Royal couple”

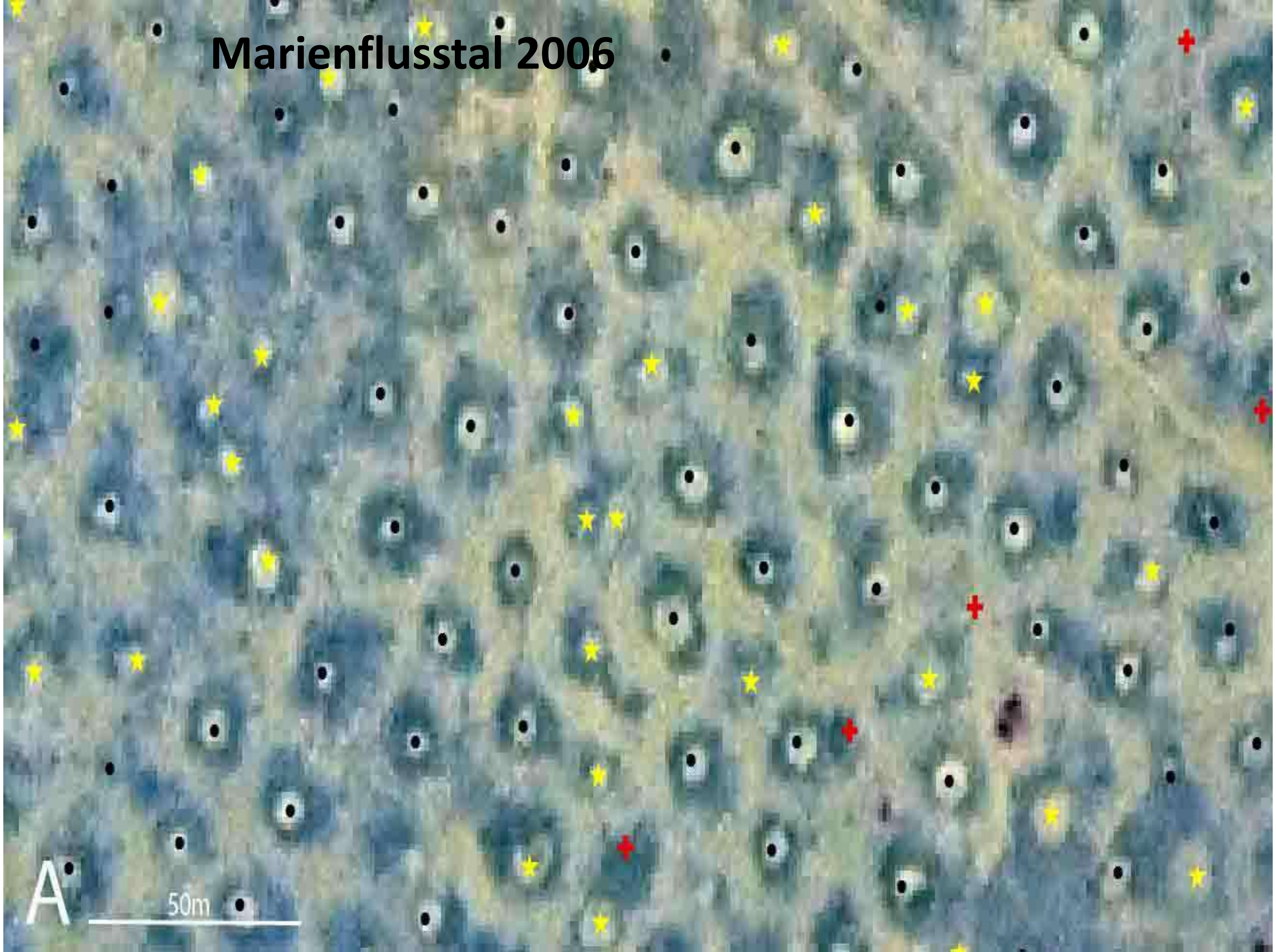


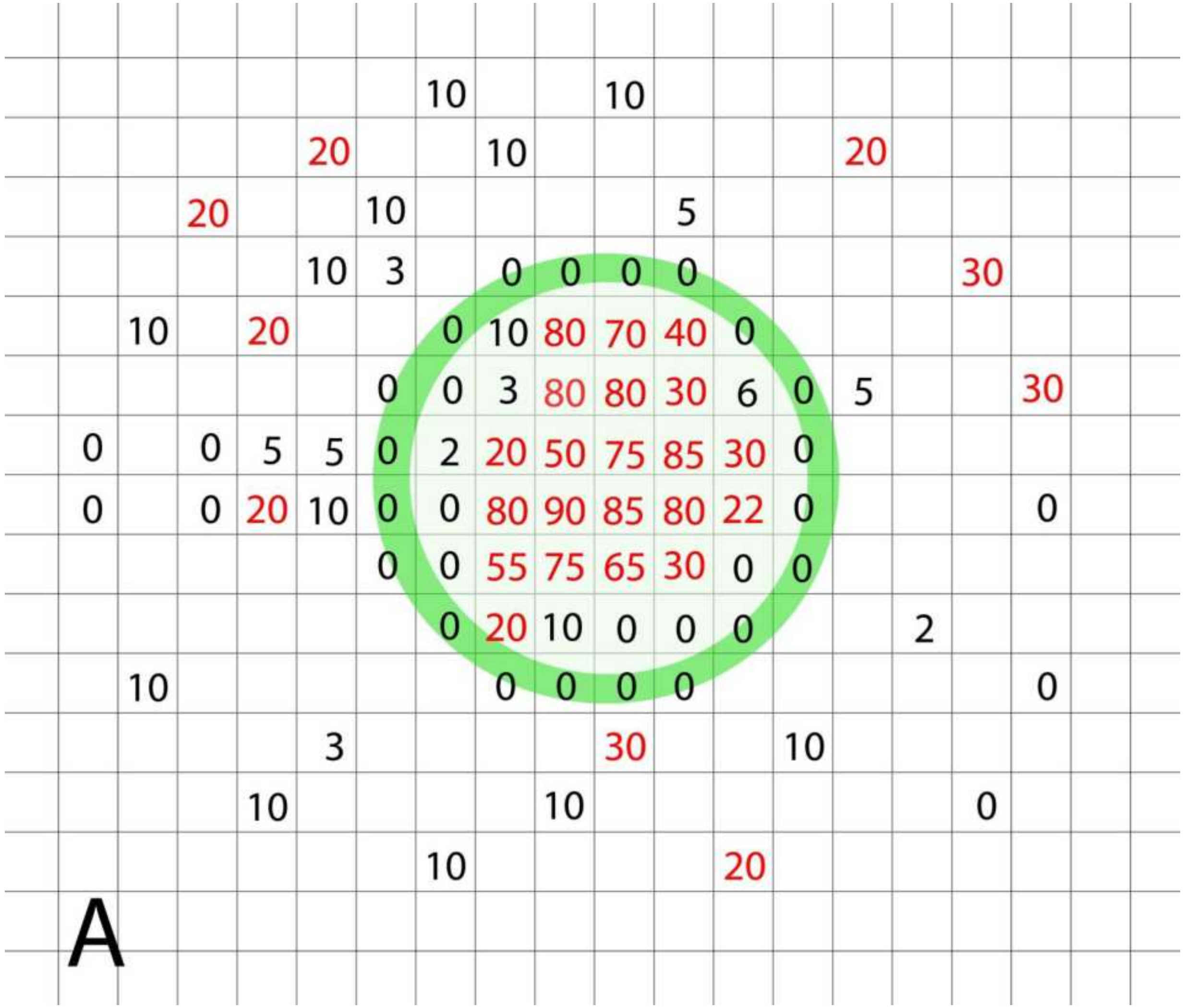
After good rain years numerous founder colonies with irregular shape establish, mostly in distance to the old well-established fairy circles.

Marienflusstal 1956

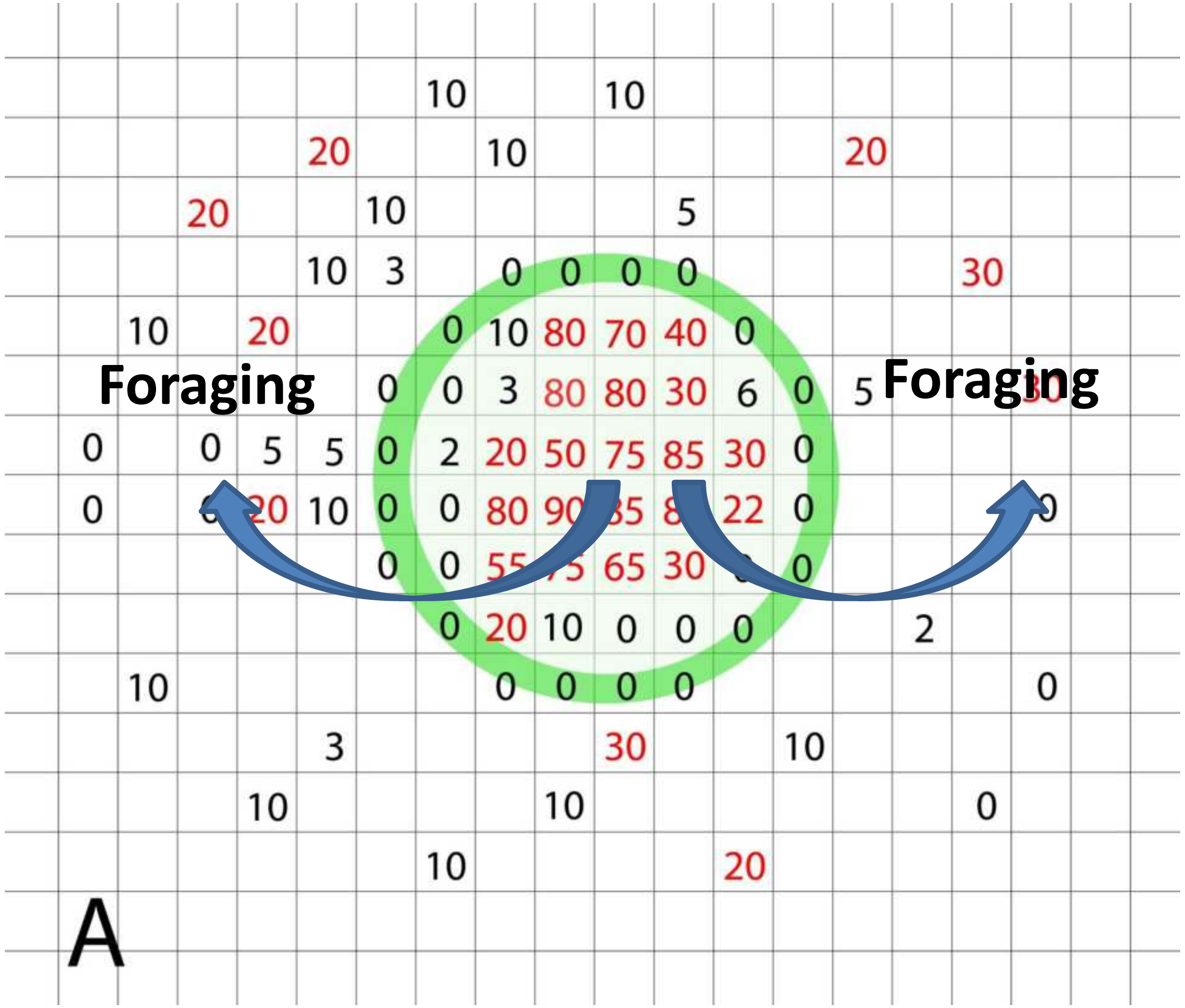


Black: persistent in 1956 & 2006
Yellow: Only in 2006
Red: Only in 1956

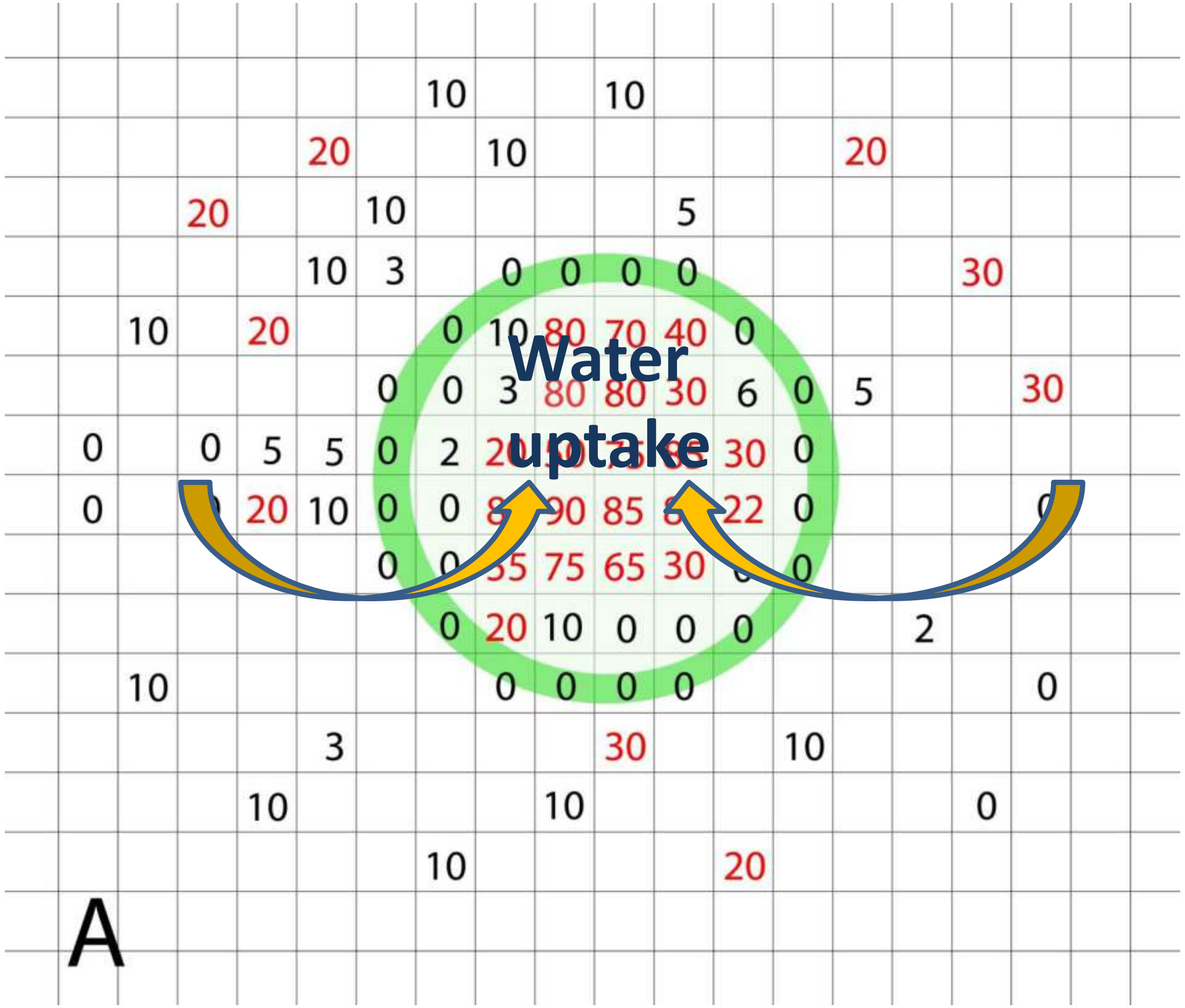

Marienflusstal 2006
A
50m



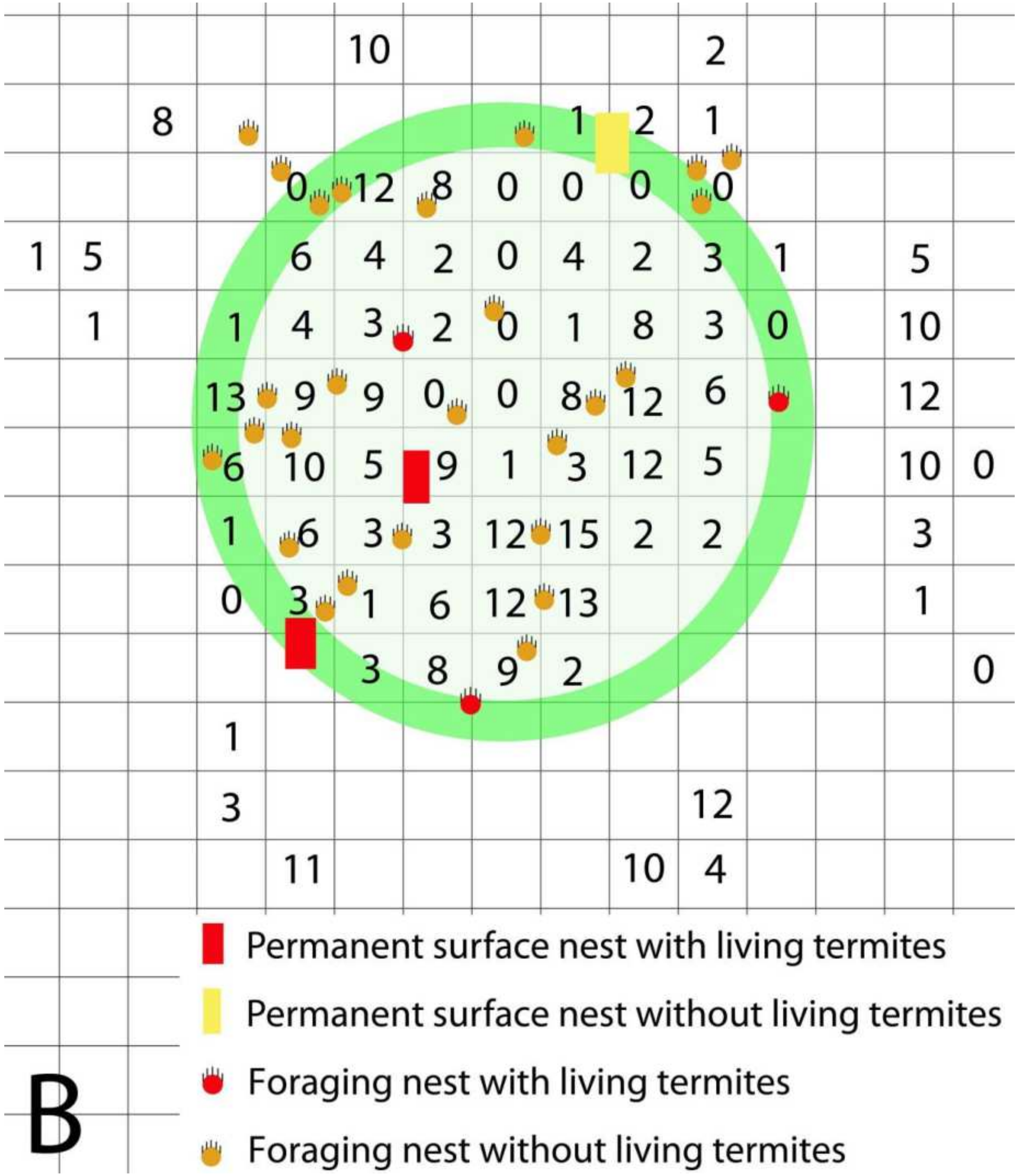
Science **339**, 1618 (2013);



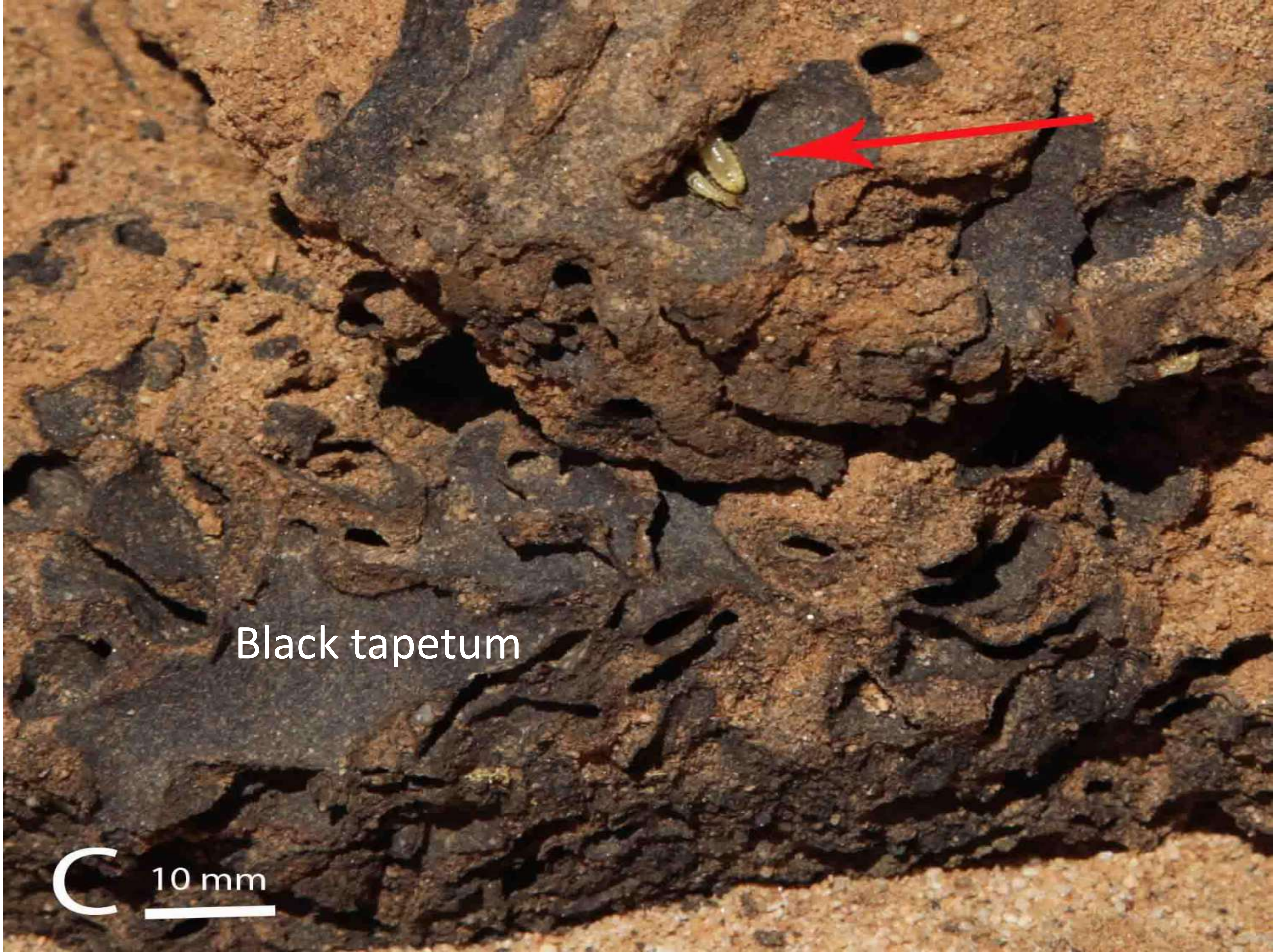
Termite movements

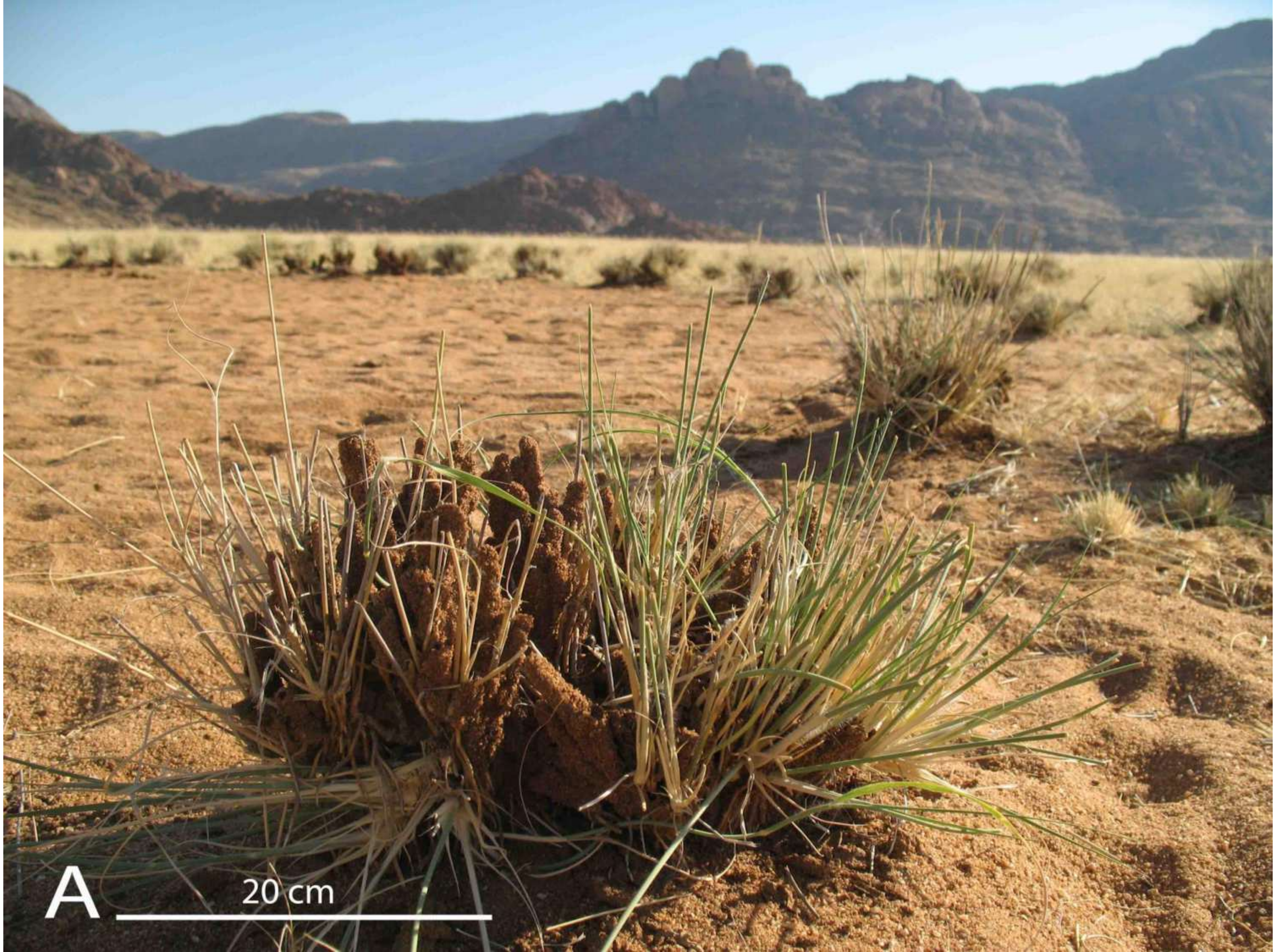


Termite movements

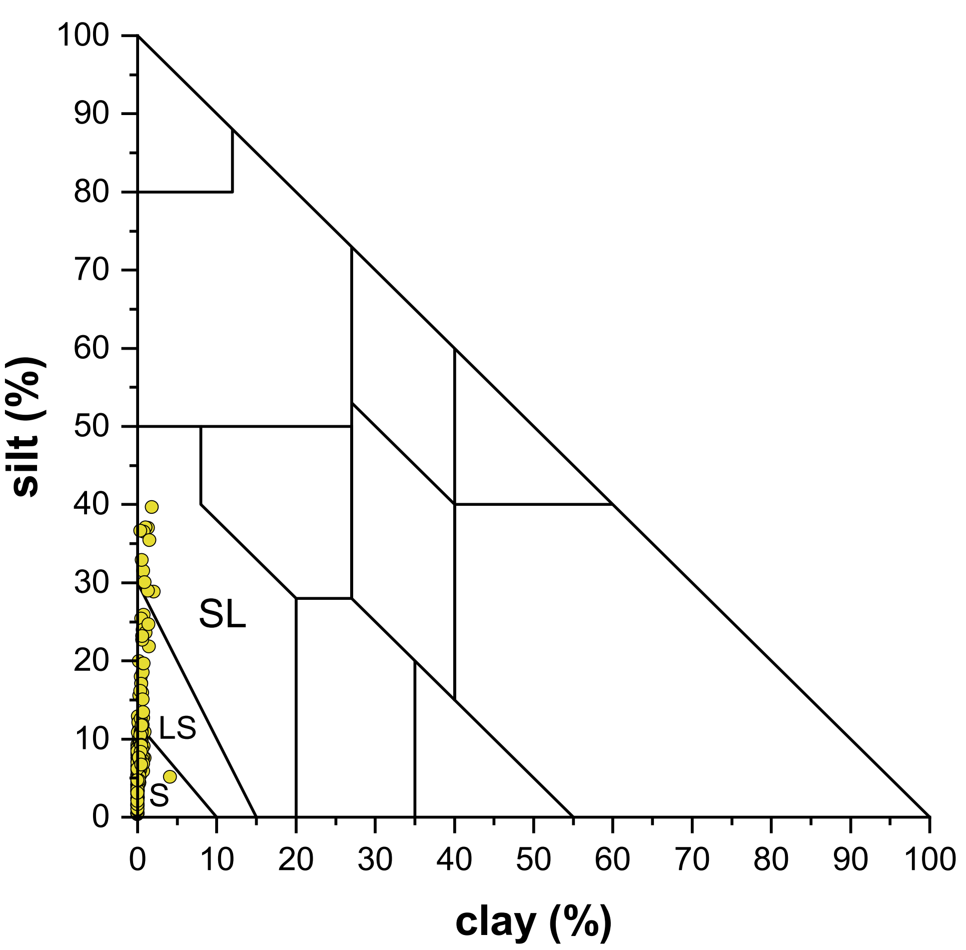

Permanent surface nest with living termites
Permanent surface nest without living termites
Foraging nest with living termites
Foraging nest without living termites
B

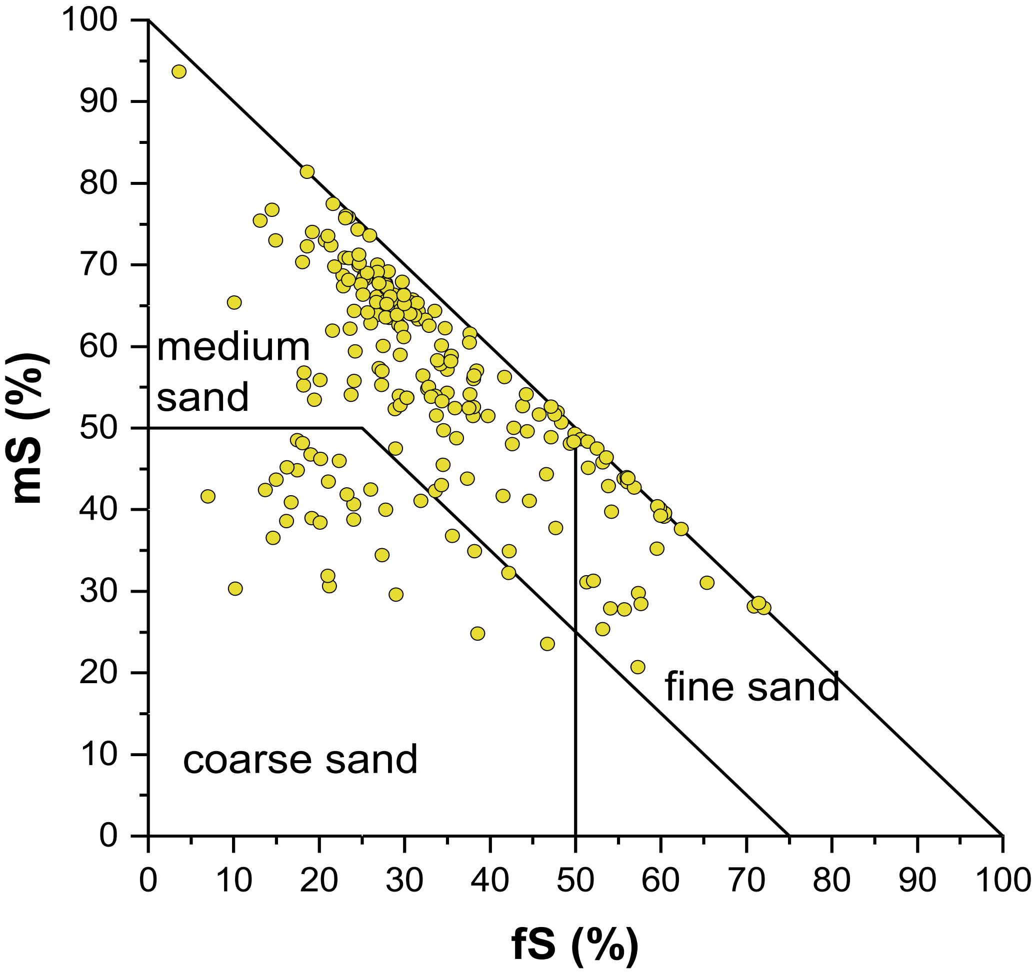

10 cm
D


Black tapetum
C
10 mm


A
20 cm

Soil texture (n=235): medium to coarse sand





Awasib, September 1991

Geluk, April 2012

Spatial and temporal patterns of distribution of water within FCs

October 2006, 8 month after last rain

Depth[cm]\Position	Matrix	Per. Belt	Half radius	Center	Half radius	Per. Belt	Matrix
10 cm	2.4	2.3	2.7	3.1			
20 cm	2.5	2.6	4.0	4.5			
30 cm	3.0	3.2	4.8	6.0			
40 cm	3.2	4.3	6.0	6.0			
50 cm	3.9	4.6	6.0	6.0			
60 cm	4.4	6.0	6.0	6.5			
70 cm	4.7	6.5	6.5	6.5			
80 cm	5.2	6.5	6.5	6.5			
90 cm	6.0	6.5	6.5	7.0			
100 cm	6.0	6.5	7.0	7.0			
$\sum H_2O$[mm] in 0-100cm:	39.05	46.60	53.25	56.35			

January 2007, 11 month after last rain

Depth[cm]\Position	Matrix	Per. Belt	Half radius	Center	Half radius	Per. Belt	Matrix
10 cm	4.6	1.7	3.7	4.6			
20 cm	3.9	2.7	4.7	5			
30 cm	3.6	3.4	6.2	6.7			
40 cm	5.4	4.3	5.9	6.4			
50 cm	4.3	3.9	6.4	6.2			
60 cm	3.7	3	6.8	7.6			
70 cm	5.1	3.6	5.6	9.1			
80 cm	3.8	4.7	6.7	6.7			
90 cm	4.9	5	5	7.0			
100 cm	4.7	5.2	5.9	6.8			
$\sum H_2O$[mm] in 0-100cm:	43.95	37.75	55.80	65.00			

March 2007, after 28 mm of rain Jan to Mar 2007

Depth[cm]\Position	Matrix	Per. Belt	Half radius	Center	Half radius	Per. Belt	Matrix
10 cm	4.9	4.6	5.3	4.4			
20 cm	5.9	5.4	7.2	8.9			
30 cm	6.0	5.6	9.3	9.1			
40 cm	5.3	5.5	8.6	9			
50 cm	5.2	5.6	8.2	9.2			
60 cm	4.1	5.5	8.5	8.8			
70 cm	5.2	5.4	9.1	9.4			
80 cm	4.9	5.2	9	9.5			
90 cm	4.9	5.4	9.2	10.1			
100 cm	4.6	5.3	8.2	9.9			
$\sum H_2O$[mm] in 0-100cm:	51.15	53.15	81.15	85.55			

December 2007, 8 months after last rain

Depth[cm]\Position	Matrix	Per. Belt	Half radius	Center	Half radius	Per. Belt	Matrix
10 cm		2.7		3.2			
20 cm		3.4		4.9			
30 cm		2		3.9			
40 cm		3.9		5			
50 cm		4.5		5.9			
60 cm		3.6		6.4			
70 cm		4.2		6.1			
80 cm		4.2		6.4			
90 cm		4.2		6.4			
100 cm		5.1		6.4			
$\sum H_2O$[mm] in 0-100cm:		36.60	-	53.00			

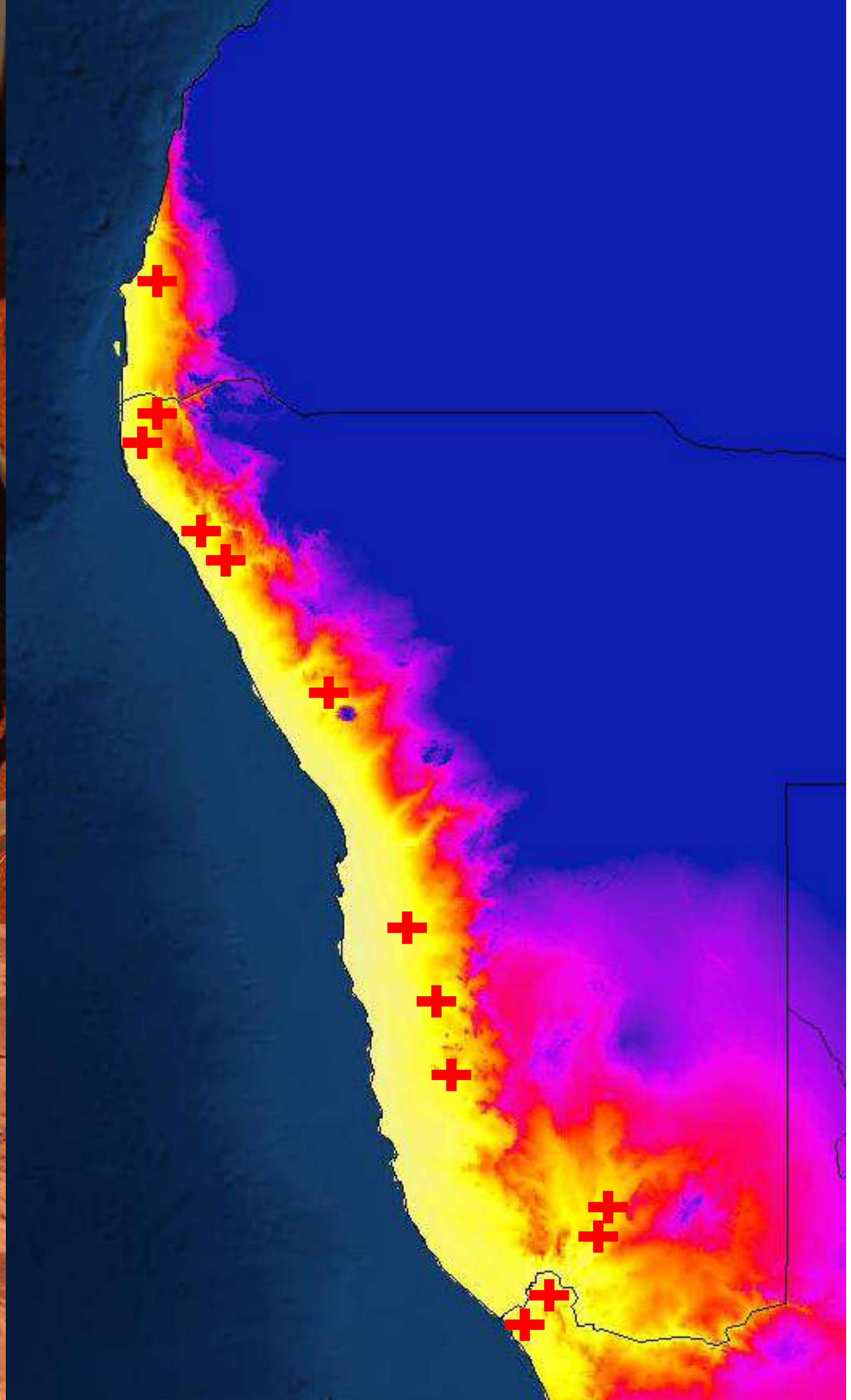
10 Feb 2008 (5 days after first good rains of the season (ca. 25mm)

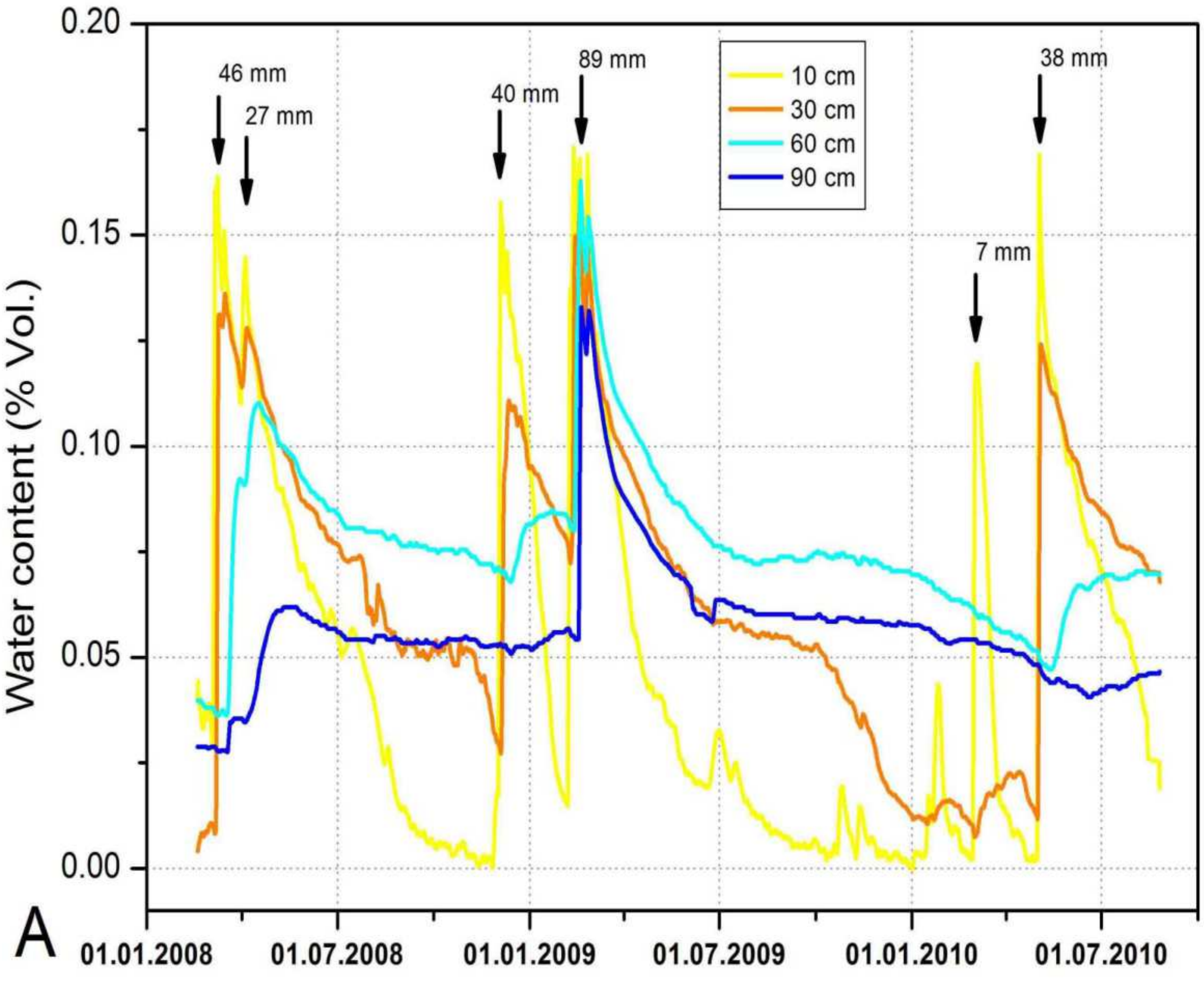
Depth[cm]\Position	Matrix	Per. Belt	Half radius	Center	Half radius	Per. Belt	Matrix
10 cm	8.9	8.5	5.2	7.7			
20 cm	5.2	5.9	5.9	6.2			
30 cm	3.4	4.9	5.5	6.8			
40 cm	3.4	3.6	5.3	5.1			
50 cm	4	4	5	6.8			
60 cm	4.2	4.3	6.3	7.3			
70 cm	4	4.1	6.2	7.6			
80 cm	4.1	3.9	7.0	6.5			
90 cm	4.5	4.3	7.1	7.4			
100 cm	4.5	4.3	7.1	7.4			
$\sum H_2O$[mm] in 0-100cm:	48.4	49.9	59.65	68.95			

Soil Moisture beneath the bare patch

Jürgens (2013) Science 339: 1618-1621

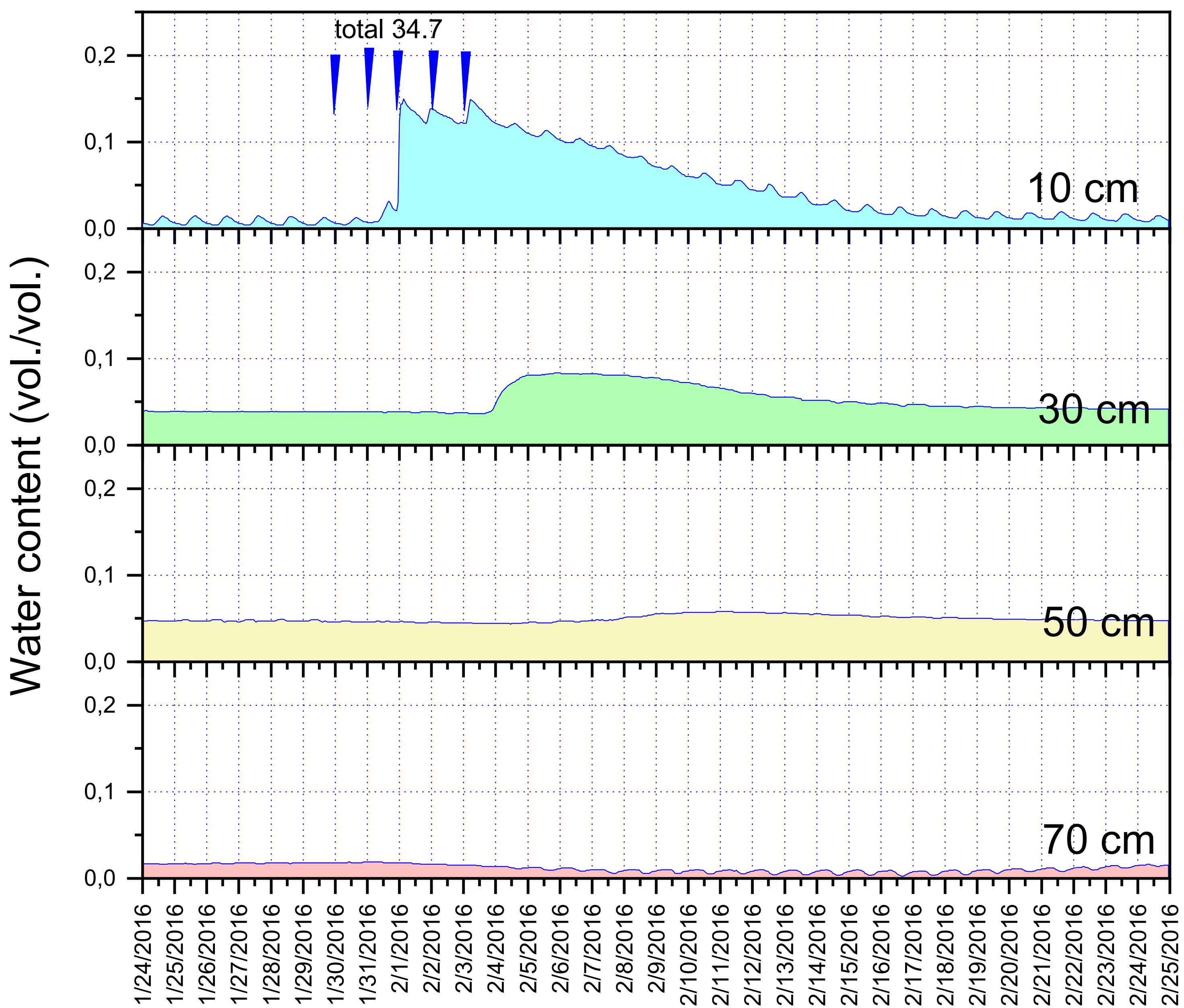

Em50 Port Configuration
Port
Sensor
Depth
Notes:
DECAGON DEVICES
Panasonic
P1
P2
P3
P4
P5
COMM PORT



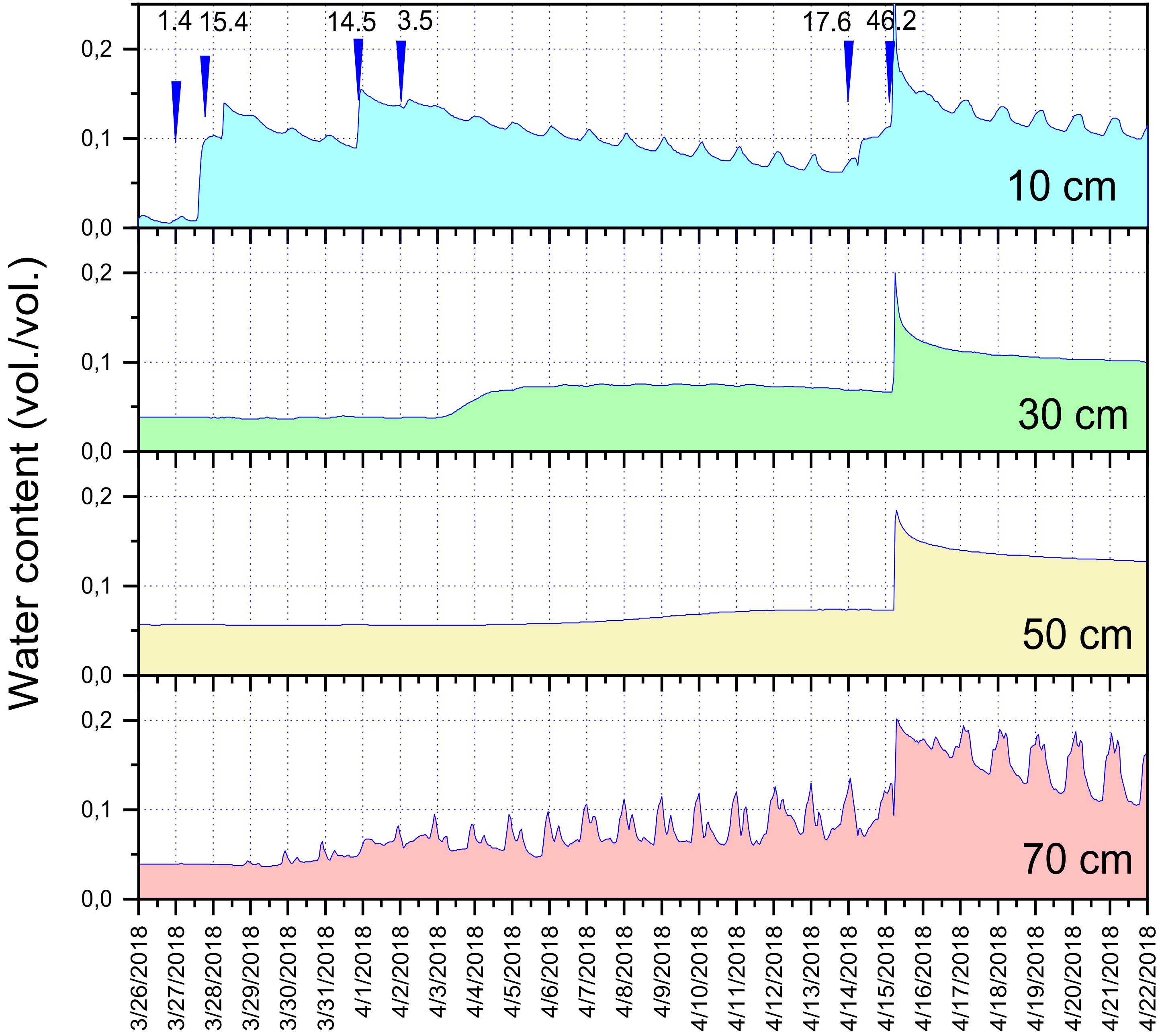


Science **339**, 1618 (2013);

Giribesvlakte January 2016

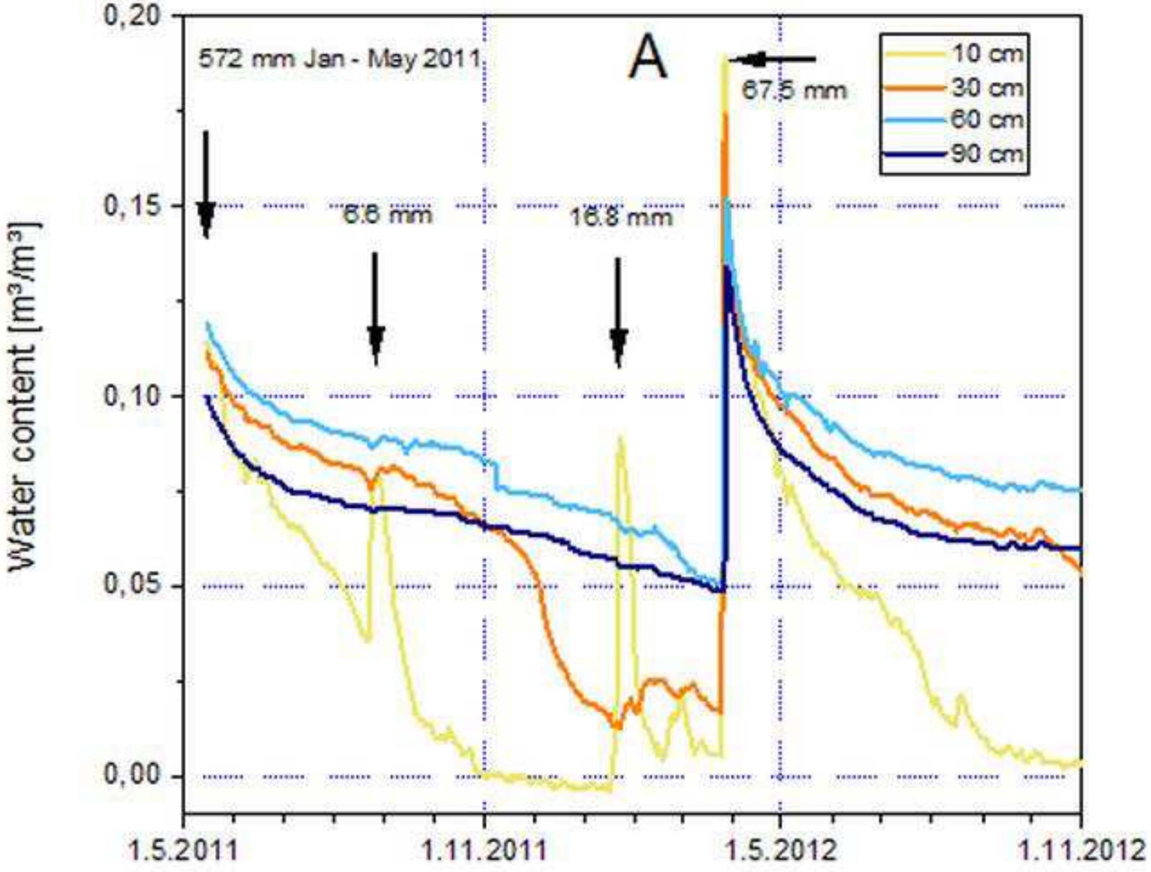


Nach insgesamt 34.7 mm Niederschlag (über 5 Tage verteilt) dringt das Wasser bis in 3 d bis 30 cm und in 8d bis 50 cm Tiefe vor. Weiter kommt es nicht. Der Anstieg in 50 cm ist nur von 4.8 --> 6.0 Vol.%. Bei vorher trockenem Boden reicht der Regen nicht aus, den Boden tiefer zu befeuchten. Der Gesamtboden hatte vor dem Regen einen Wasservorrat bis 60 cm Tiefe von 20.8 mm, der Höchstwert nach den Niederschlägen (5. Februar) betrug 49.4 mm, also eine Zunahme von 28.6 mm. Dies entspricht größenordnungsmäßig der Niederschlagsmenge abzüglich sofortiger Evaporationsverluste.

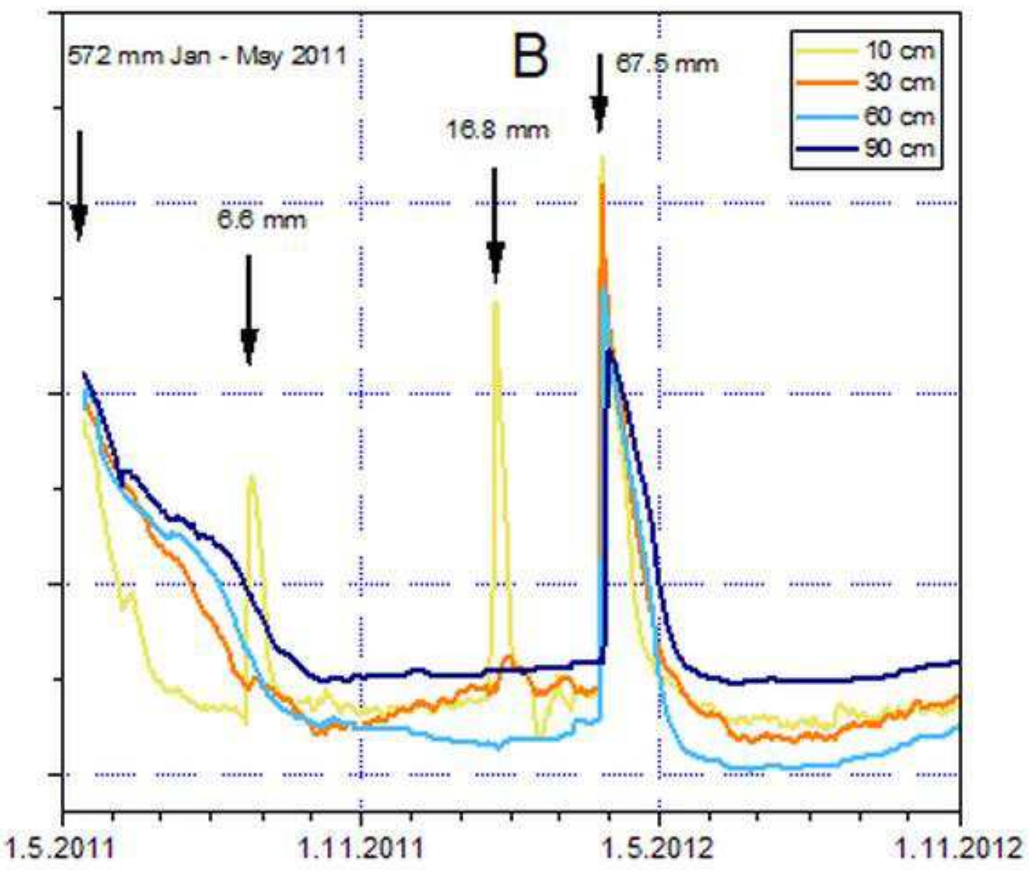


2) März 2018: Hier haben wir es mit zwei Niederschlagsphasen zu tun. Die erste entspricht mit insgesamt 34.9 mm nahezu exakt der Fall vom Januar 2016. Auch die Tiefenausbreitung ist identisch. Dann fallen aber an 2 Tagen 14+15.Aprl insgesamt 63.8 mm - auf vorbefeuchteten Boden!!. Nun findet eíne rasche Tiefenversickerung statt, die sofort auch die 70 cm Tiefe erreicht

Fairy circle



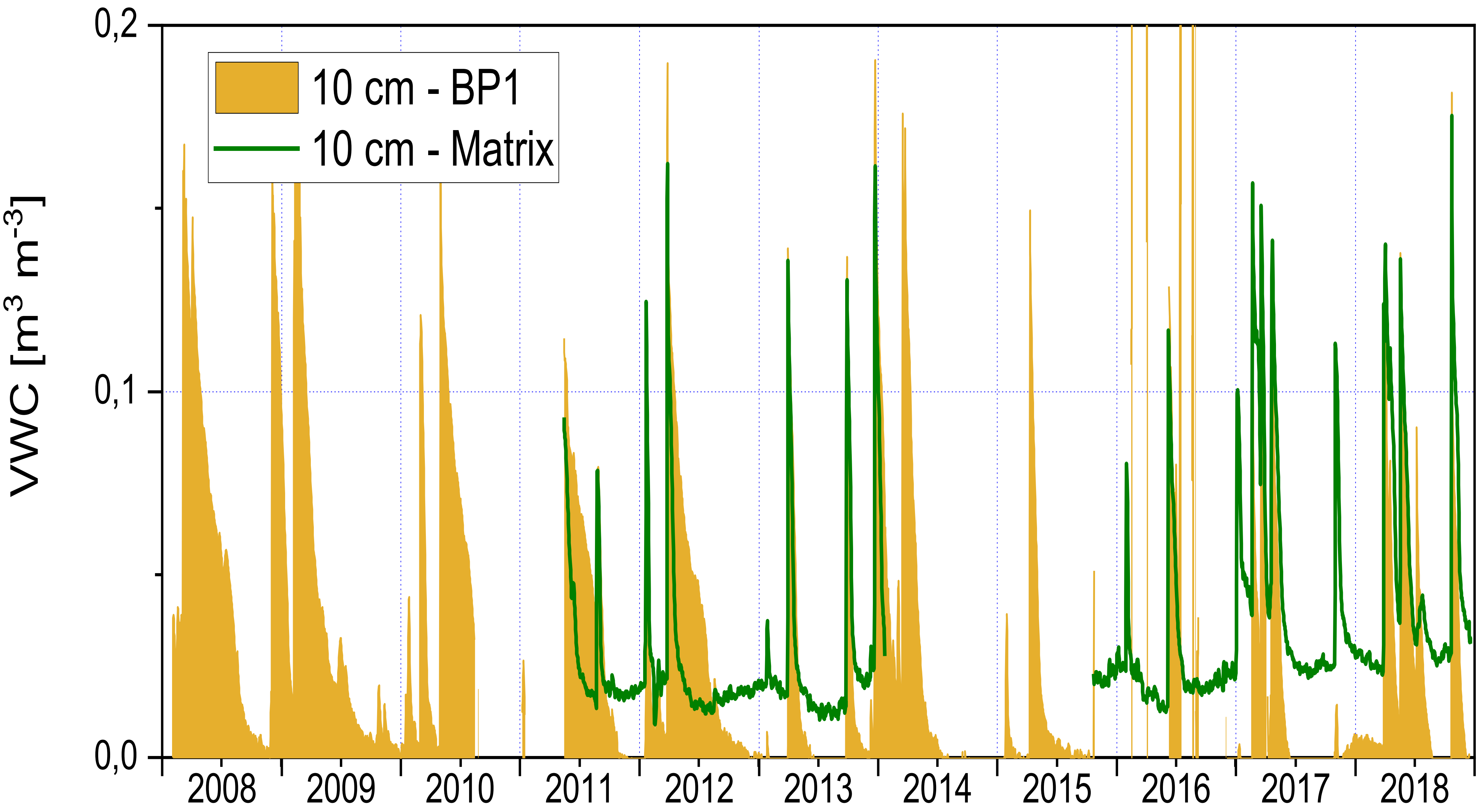
Matrix



Q3: Do fairy circles store water over longer periods of time?

Discovery No. 4: 2013

Jürgens: Because of rapid percolation and lack of evapotranspiration, water is retained and stored within the fairy circles, even during extended periods of several years of drought (Science, 2013)

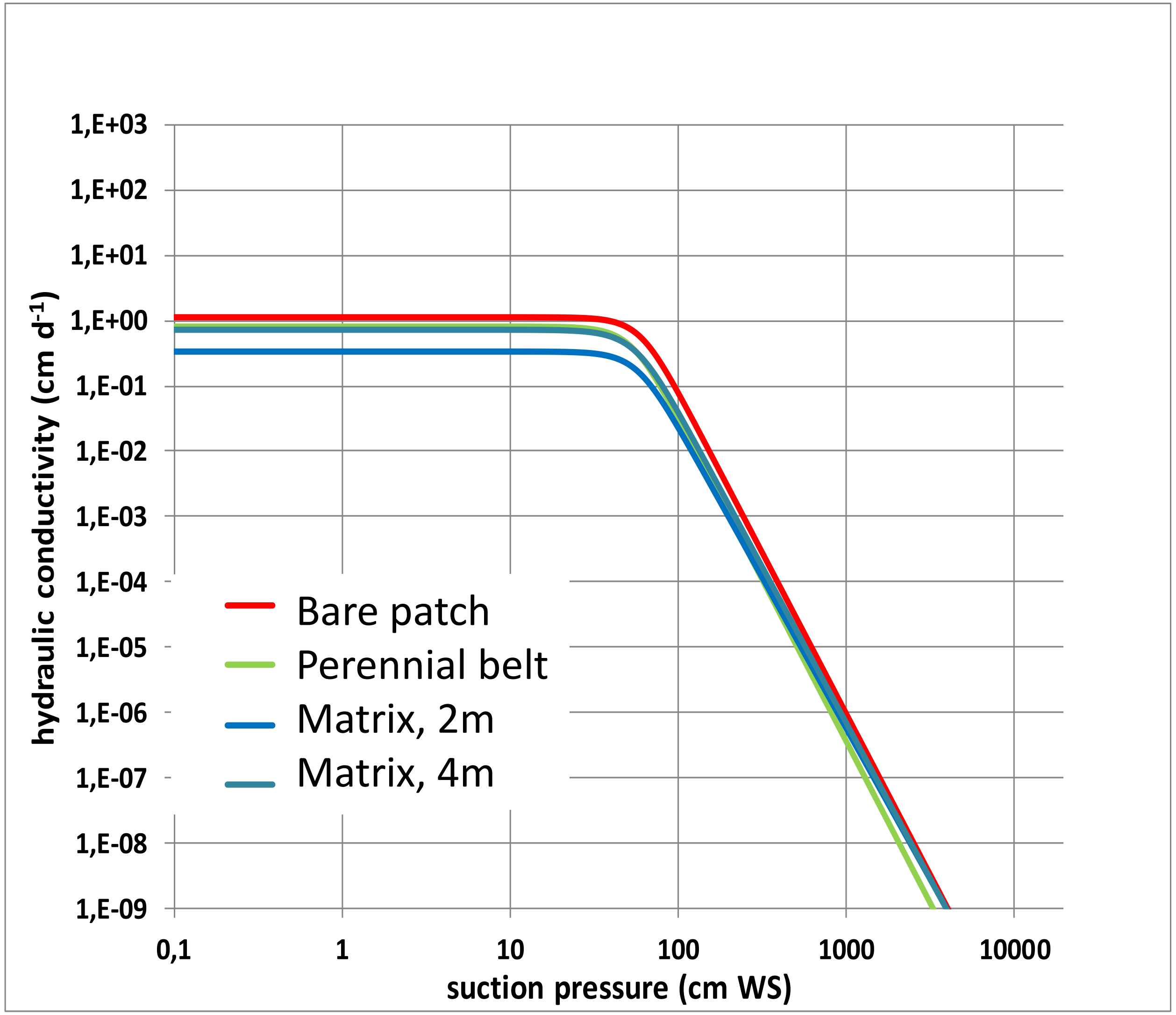


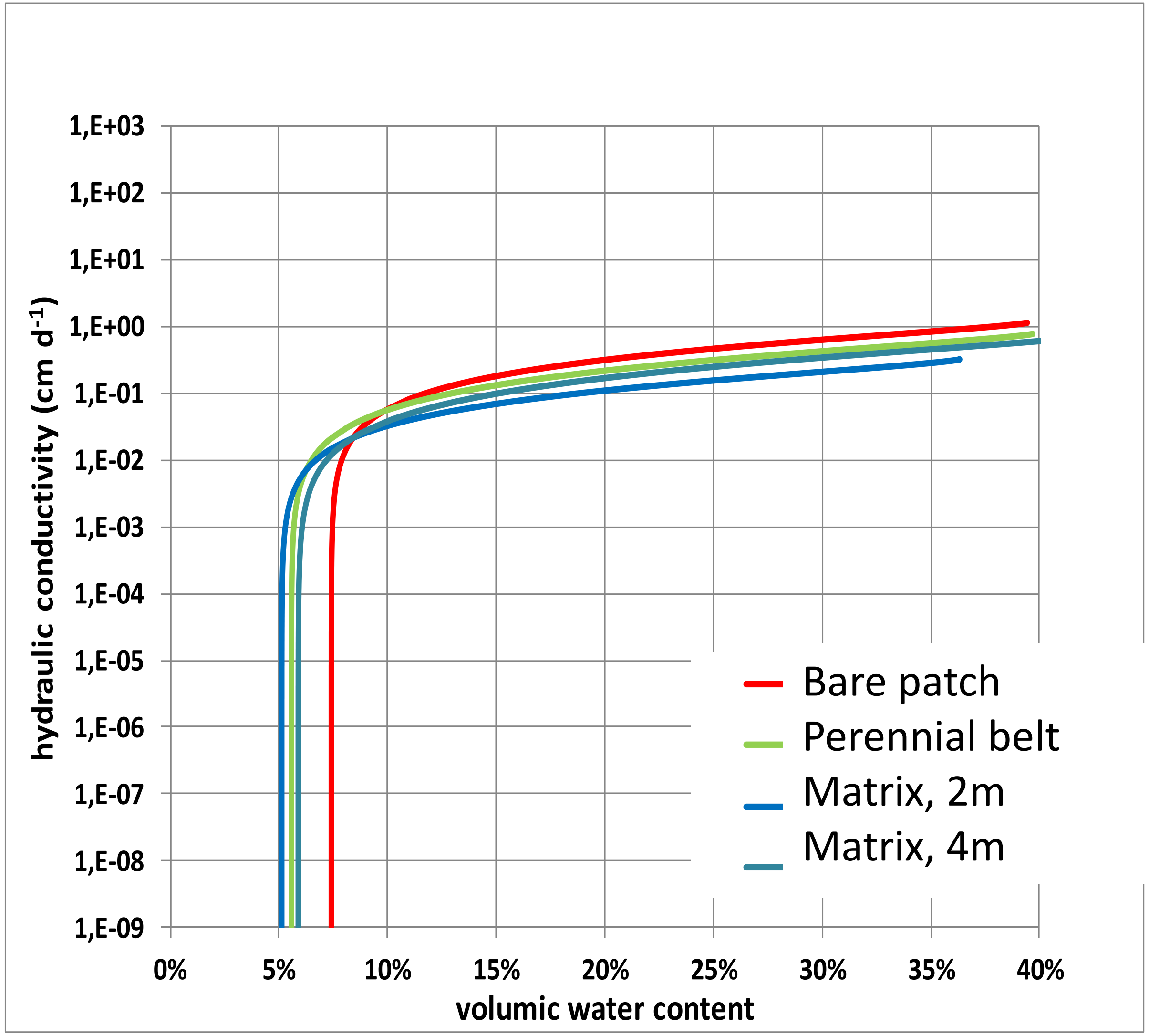
0,2
0,1
0,0
VWC [m³ m⁻³]
10 cm - BP1
10 cm - Matrix
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018


DECAGON DEVICES
MADE IN USA

Hydraulic conductivity

Dieprivier dune sand, measured in the soil physics lab, calculated with Mualem-van Genuchten equations





0,1bar 1bar 10bar

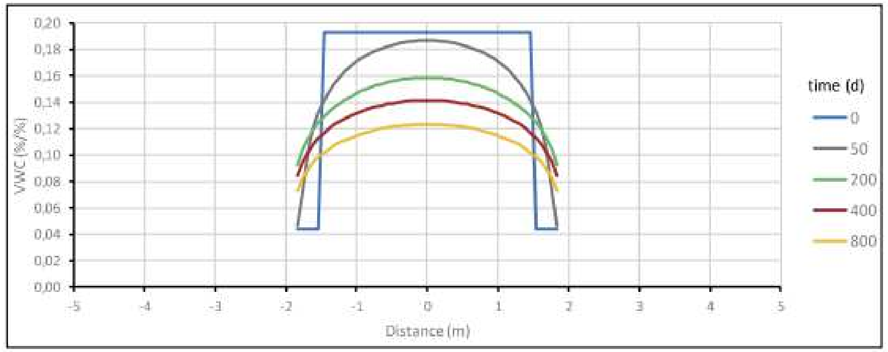


Figure 7.5.17: Change in volumetric water content (VWC) of a fine sand due to lateral drainage: bare patch radius 1.5 m.

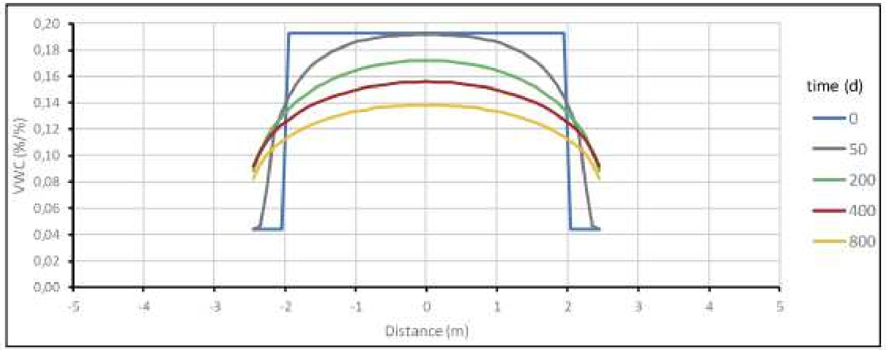


Figure 7.5.18: Change in volumetric water content (VWC) of a fine sand due to lateral drainage: bare patch radius 2 m.

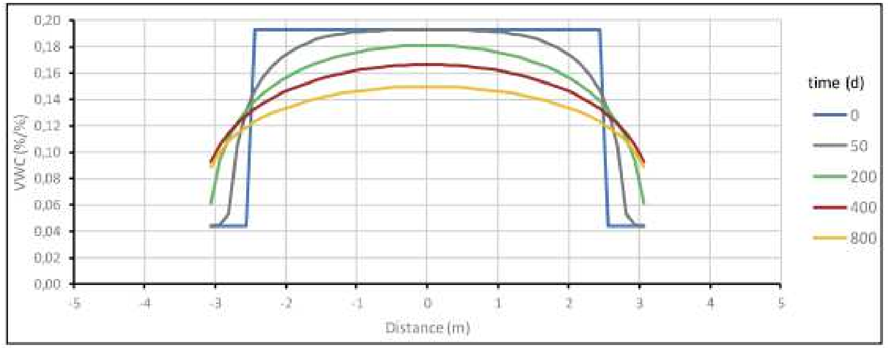


Figure 7.5.19: Change in volumetric water content (VWC) of a fine sand due to lateral drainage: bare patch radius 2.5 m.

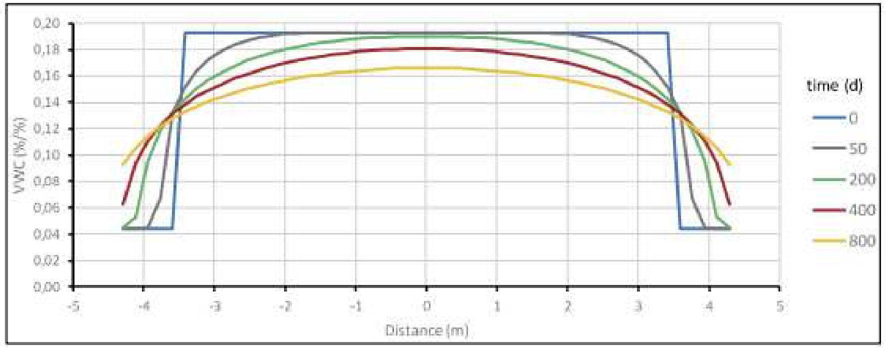


Figure 7.5.20: Change in volumetric water content (VWC) of a fine sand due to lateral drainage: bare patch radius 3 m.

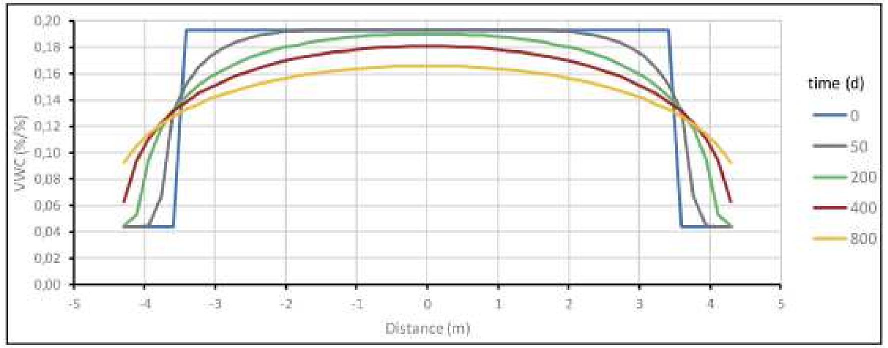


Figure 7.5.21: Change in volumetric water content (VWC) of a fine sand due to lateral drainage: bare patch radius 3.5 m.

Q3: Do fairy circles store water over longer periods of time?

Discovery No. 5: 2022

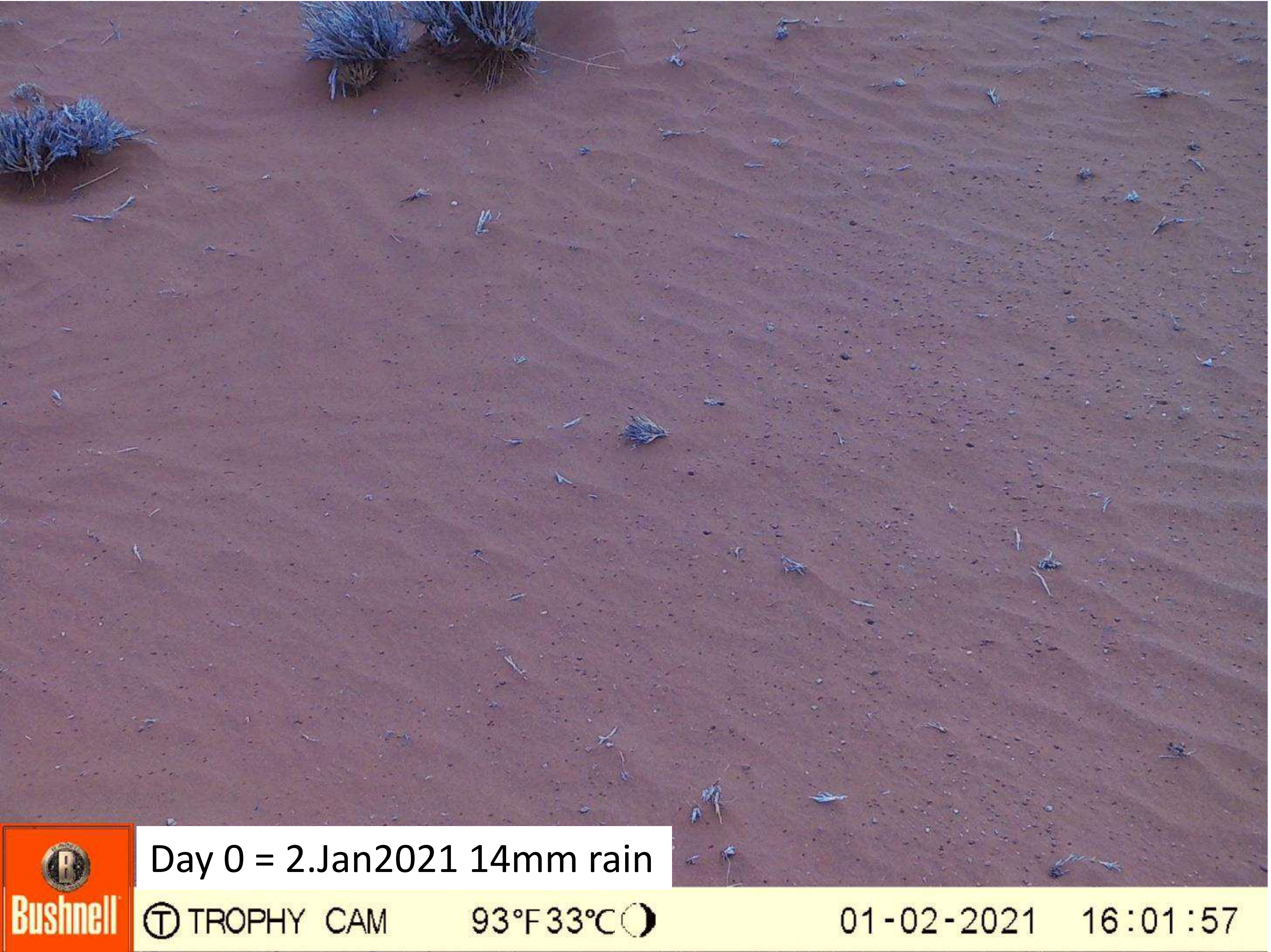
Gröngröft & Jürgens 2022: The physical properties of sand drastically reduce the lateral drainage and allow storage of rain water for one year of several ones, depending on the diameter of the bare patch (B&E, 2022)

Q6: How do sand termites kill the freshly germinated plants in the bare patch during the annual cleaning process?

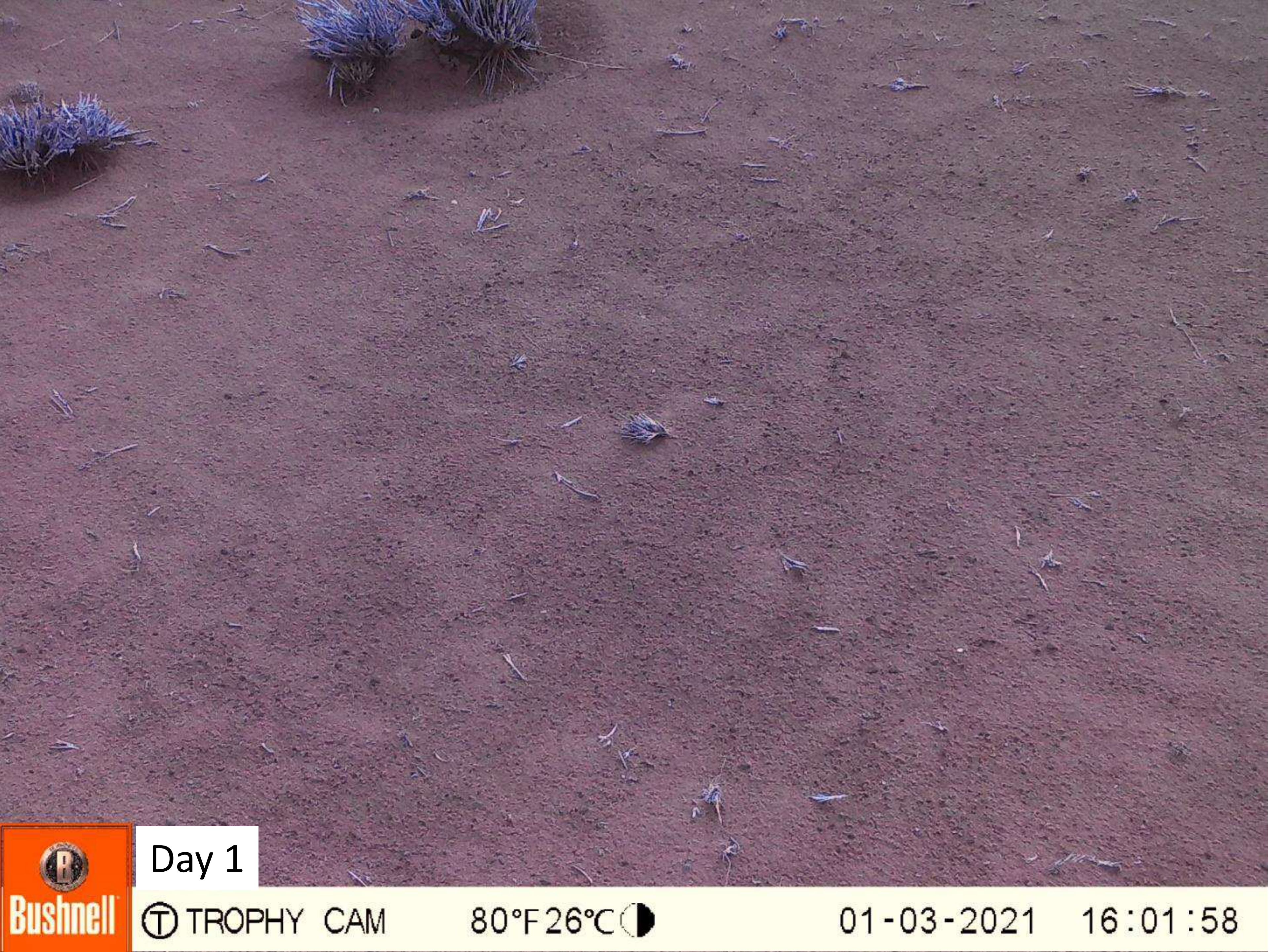
Discovery No. 7: 2013 & 2022

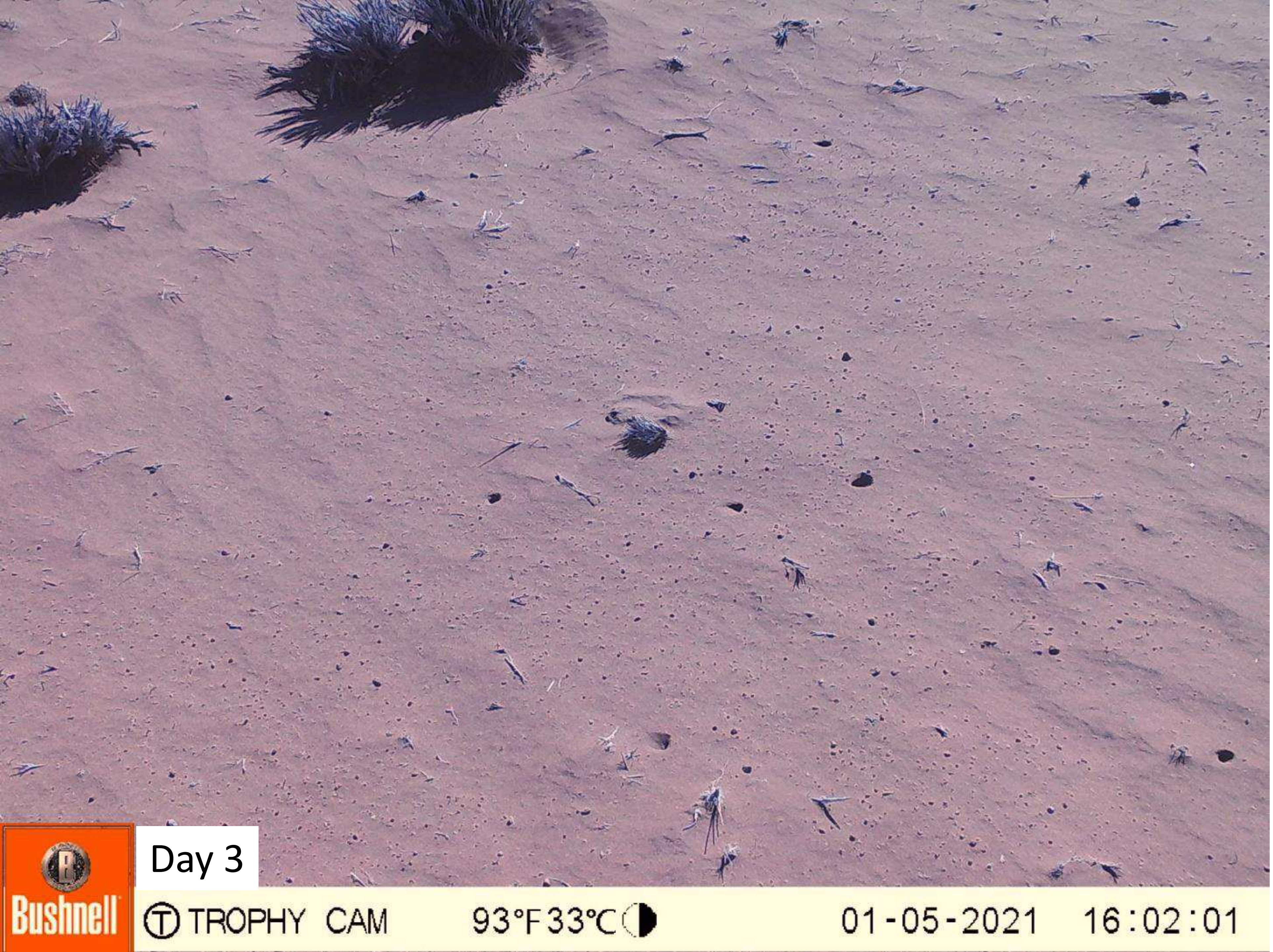
By localized subterranean herbivory, during the weeks after a good rainfall, when the soil is still moist, starting in the centre of the bare patch and progressing outwards.

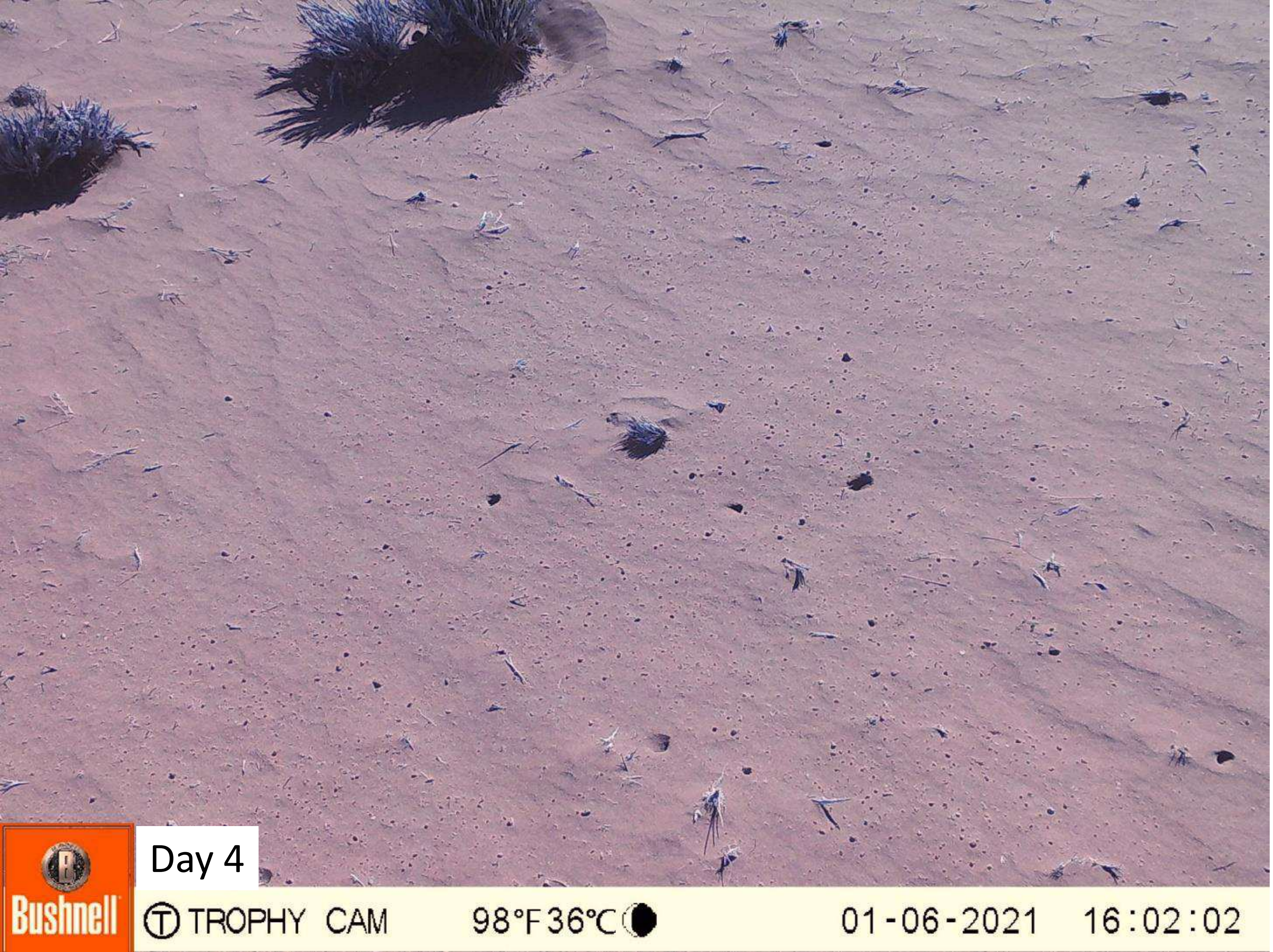

F27
F29
F99



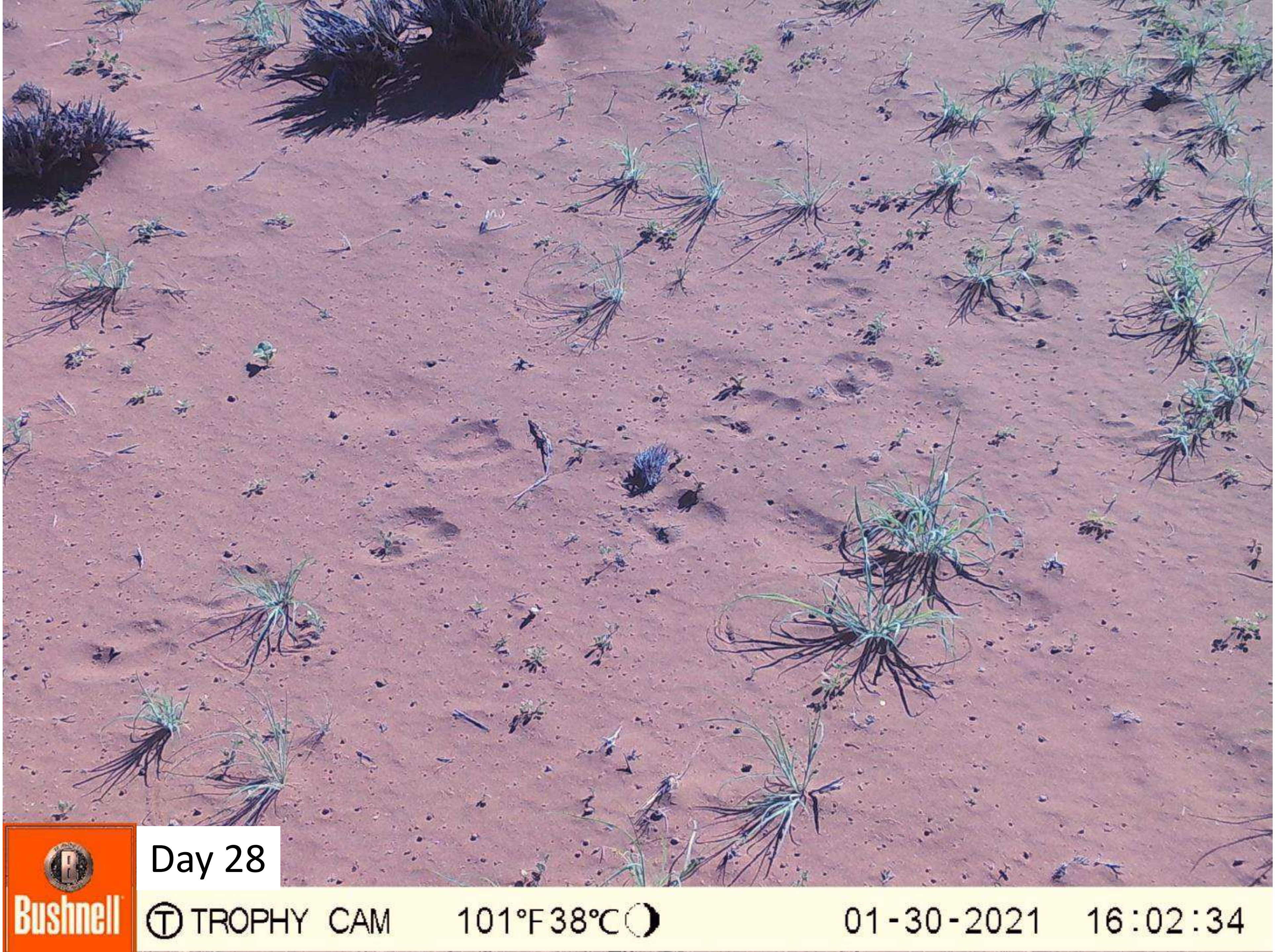
Day 0 = 2.Jan2021 14mm rain


Day 1
Bushnell
TROPHY CAM
80°F 26°C
01-03-2021
16:01:58

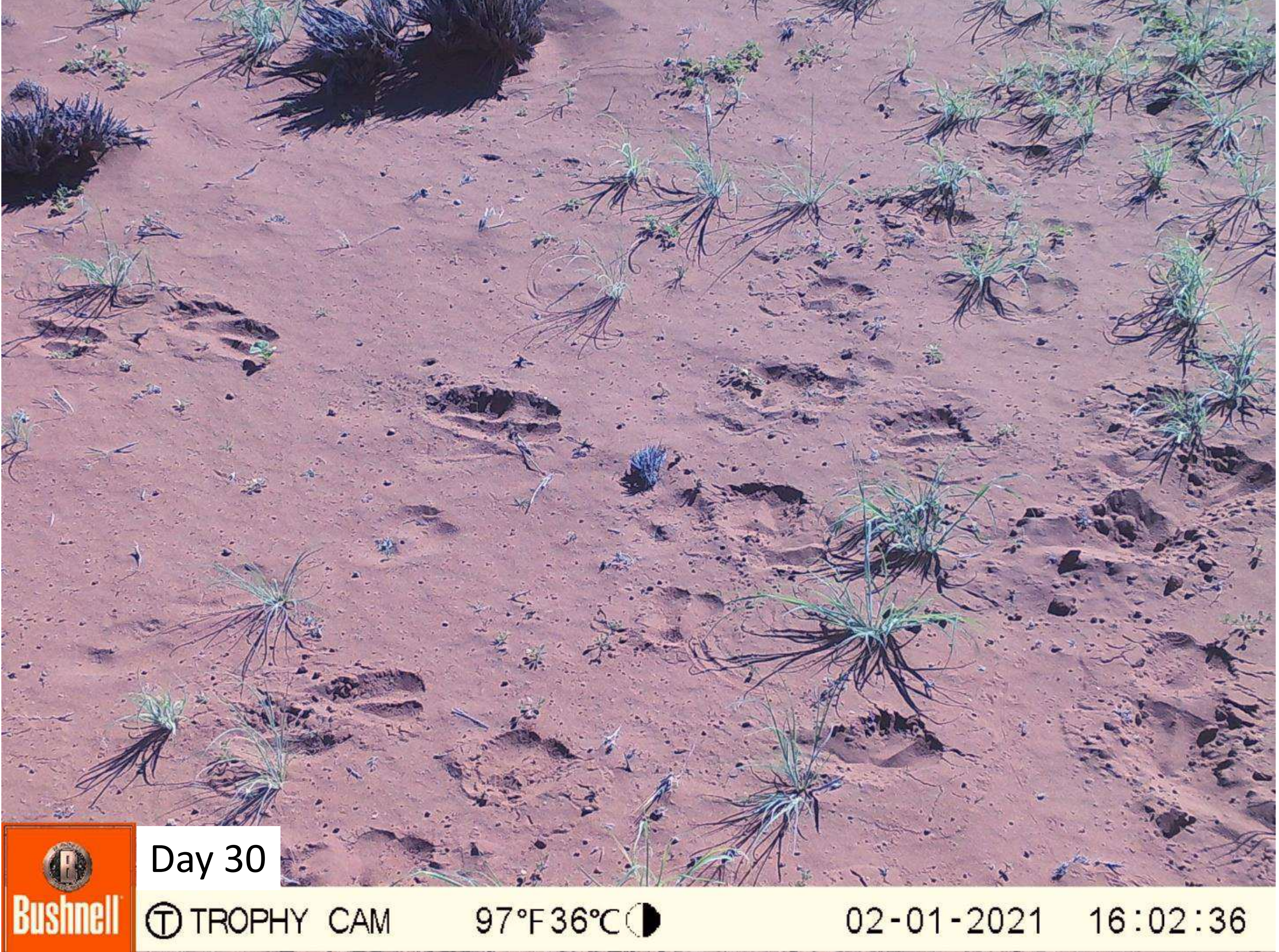

Day 3
Bushnell
TROPHY CAM
93°F 33°C
01-05-2021
16:02:01

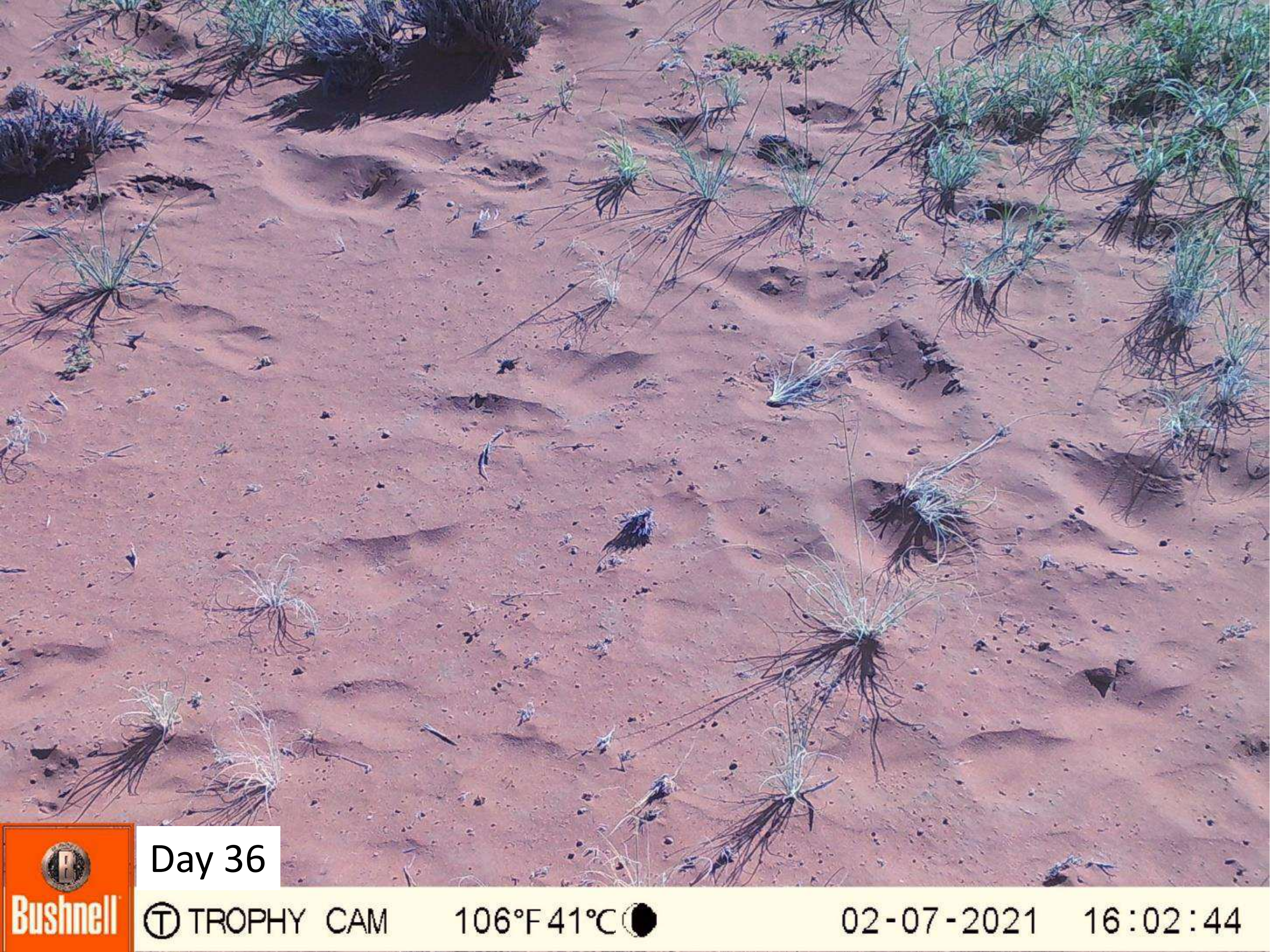

Day 4
Bushnell
TROPHY CAM
98°F 36°C
01-06-2021
16:02:02


Day 17
Bushnell
TROPHY CAM
106°F 41°C
01-19-2021
16:02:20



Day 28


Day 30
Bushnell
TROPHY CAM
97°F 36°C
02-01-2021 16:02:36

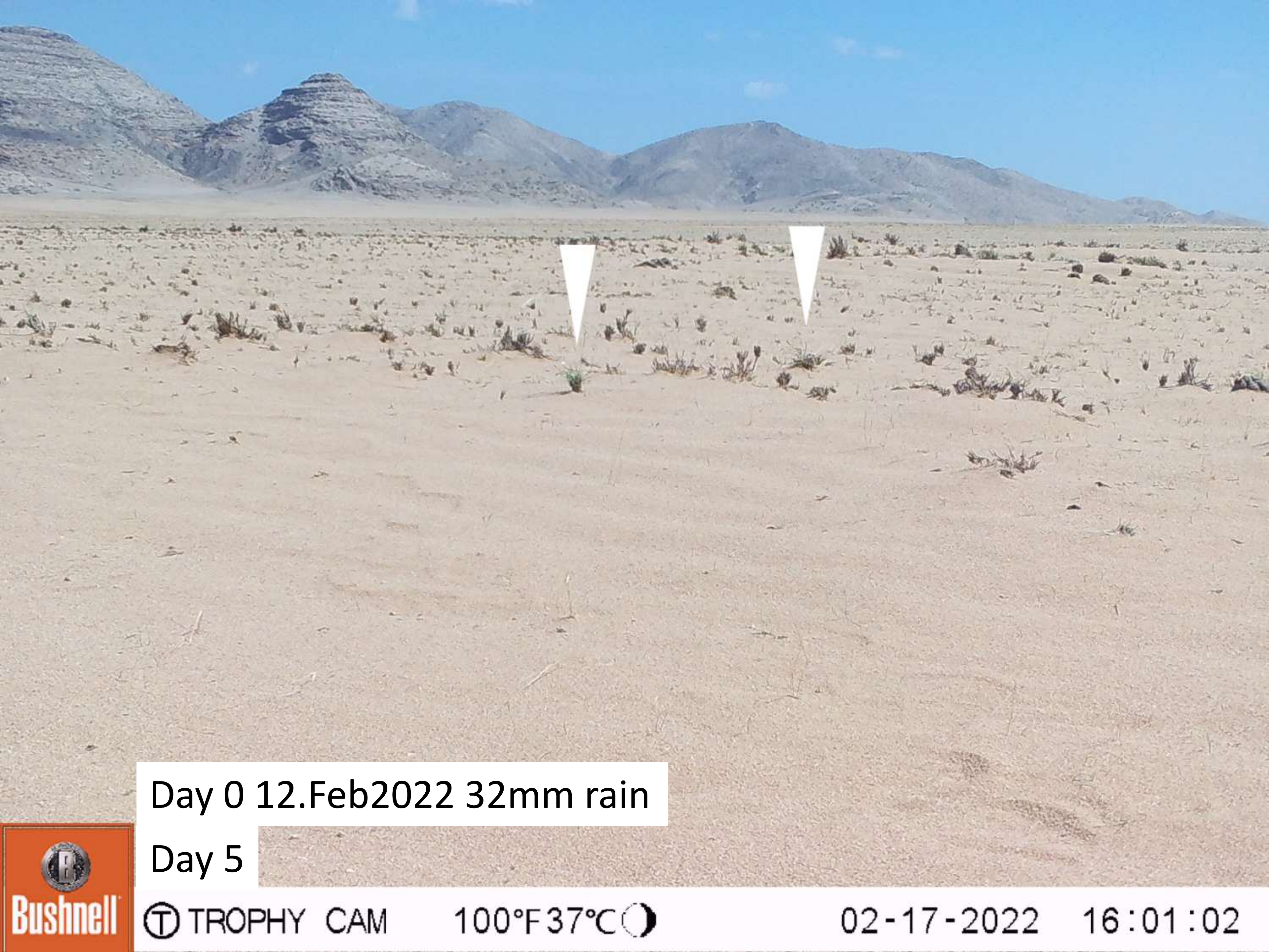

Day 36
Bushnell
TROPHY CAM
106°F 41°C
02-07-2021
16:02:44

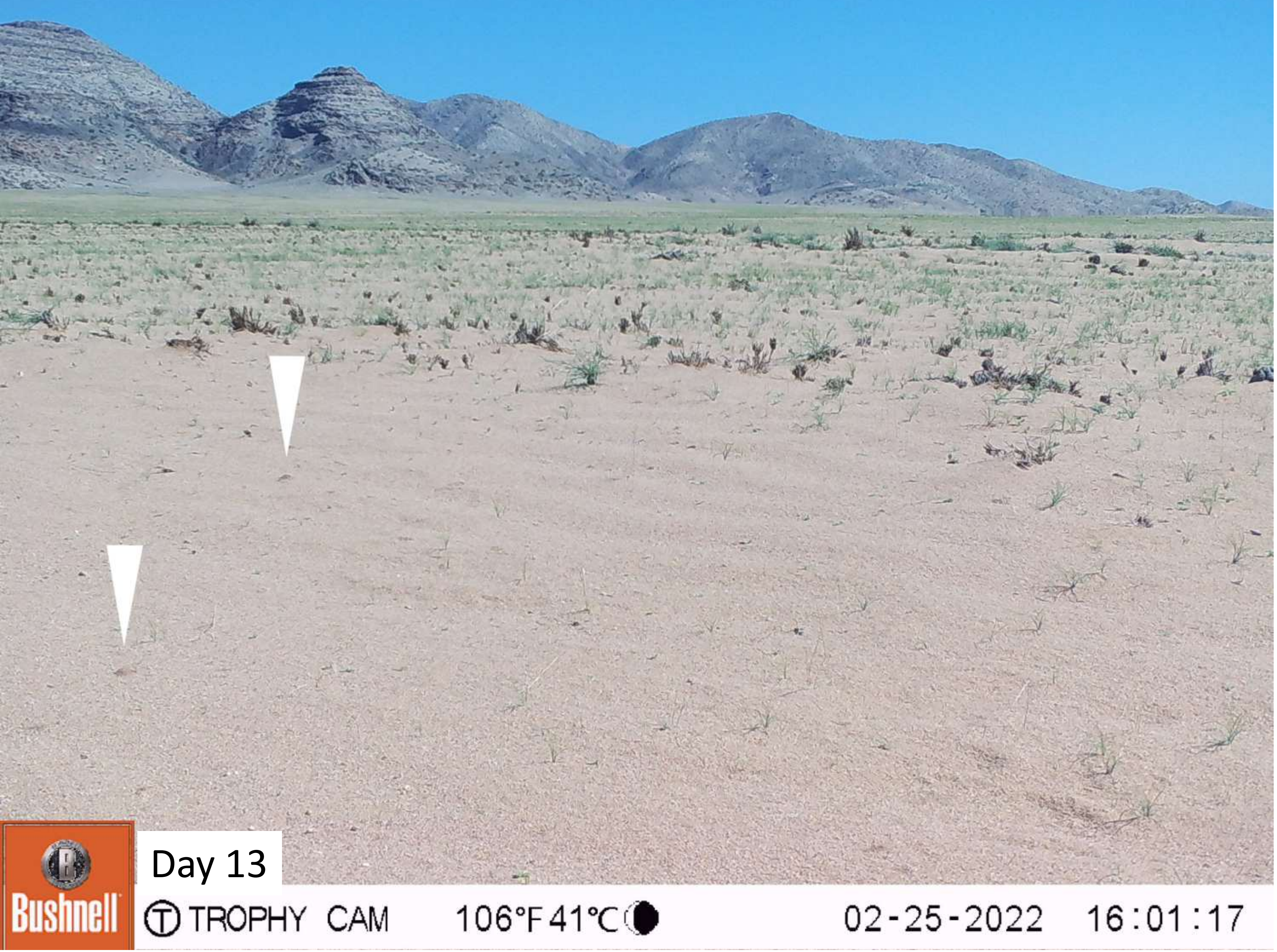

Day 51
Bushnell
TROPHY CAM
95°F 35°C
02-22-2021 16:05:13

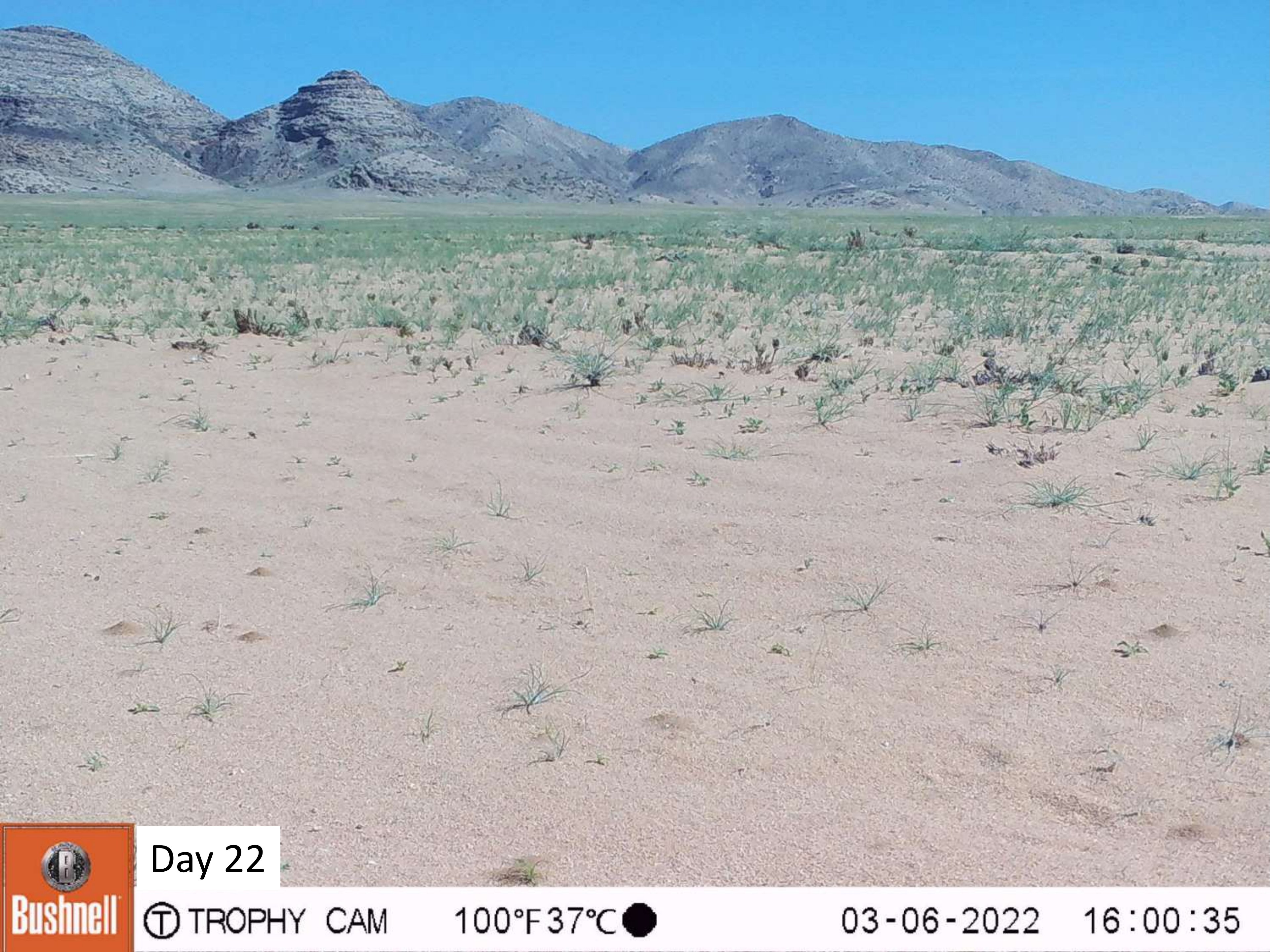

26.3.2022
Day 65


26.3.2022
Day 65


26.3.2022
ProCheck
1
SAVE
MENU
ENTER
ESC
DECAGON DEVICES
Day 65


Day 0 12.Feb2022 32mm rain
Day 5
Bushnell
TROPHY CAM
100°F 37°C
02-17-2022
16:01:02

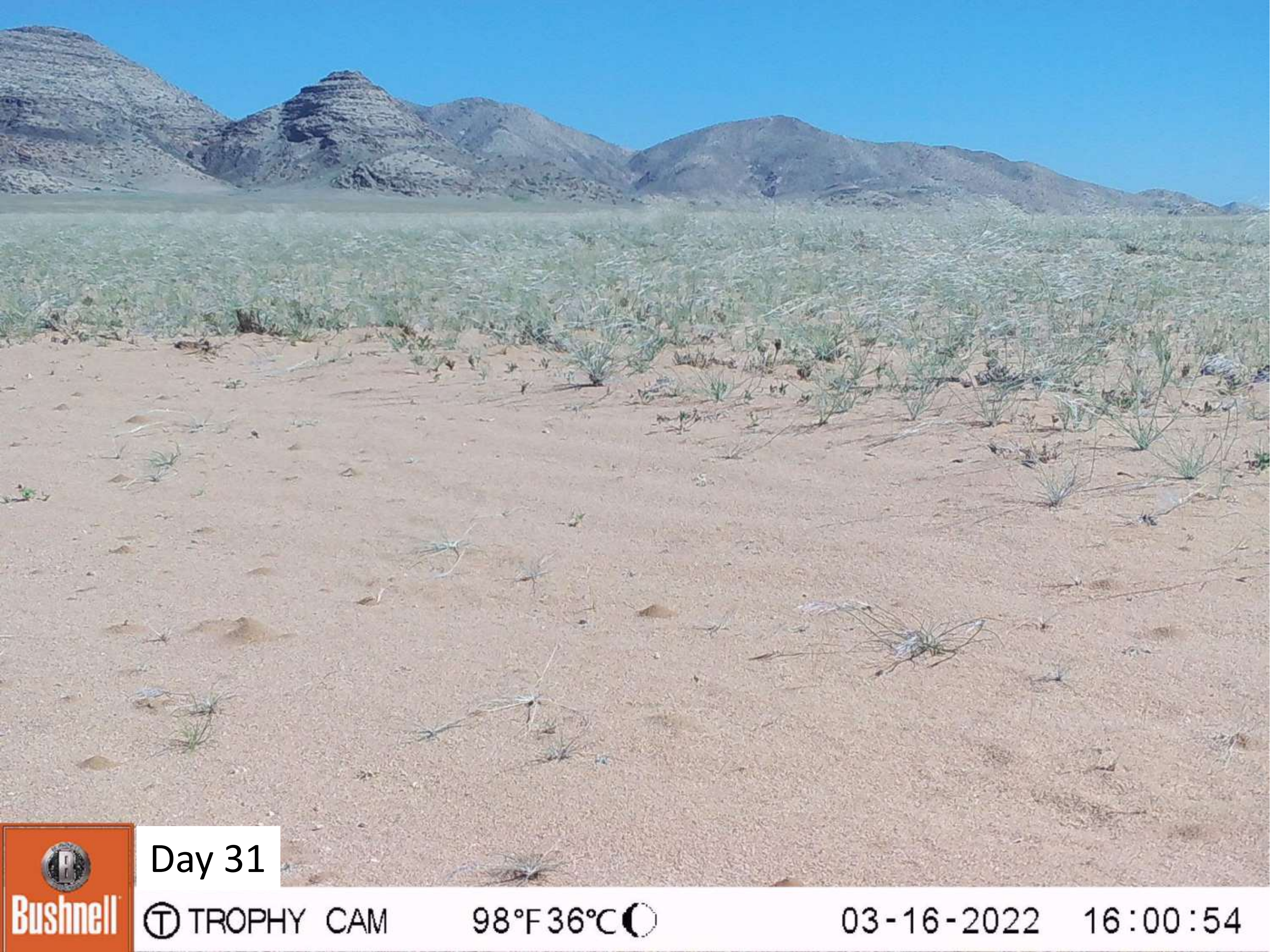

Day 13
Bushnell
TROPHY CAM
106°F 41°C
02-25-2022
16:01:17

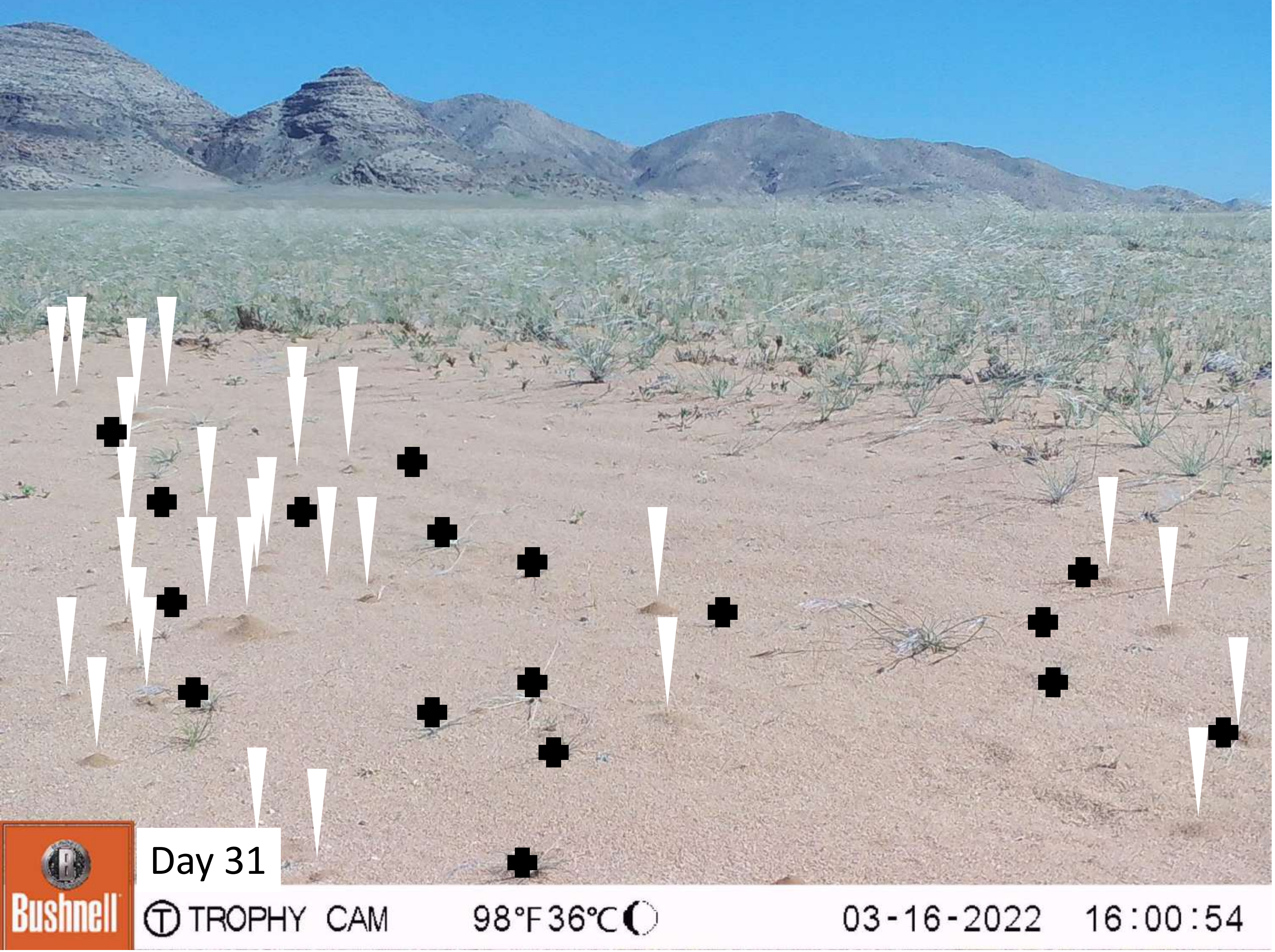


Day 22


Bushnell
TROPHY CAM
111°F 43°C
03-10-2022
16:00:43

Day 28


Day 31
Bushnell
TROPHY CAM
98°F 36°C
03-16-2022 16:00:54


Day 31
Bushnell
TROPHY CAM
98°F 36°C
03-16-2022 16:00:54

Q7: Is the damage at the grasses visible?

Discovery No. 6: 2013 & 2022

In most cases, yes. It should be further studied, whether gases from the termite nests or phytopathogenic fungi also play a role.

- Albrecht 2001

92% covered with sand, outside

32% covered with sand, inside

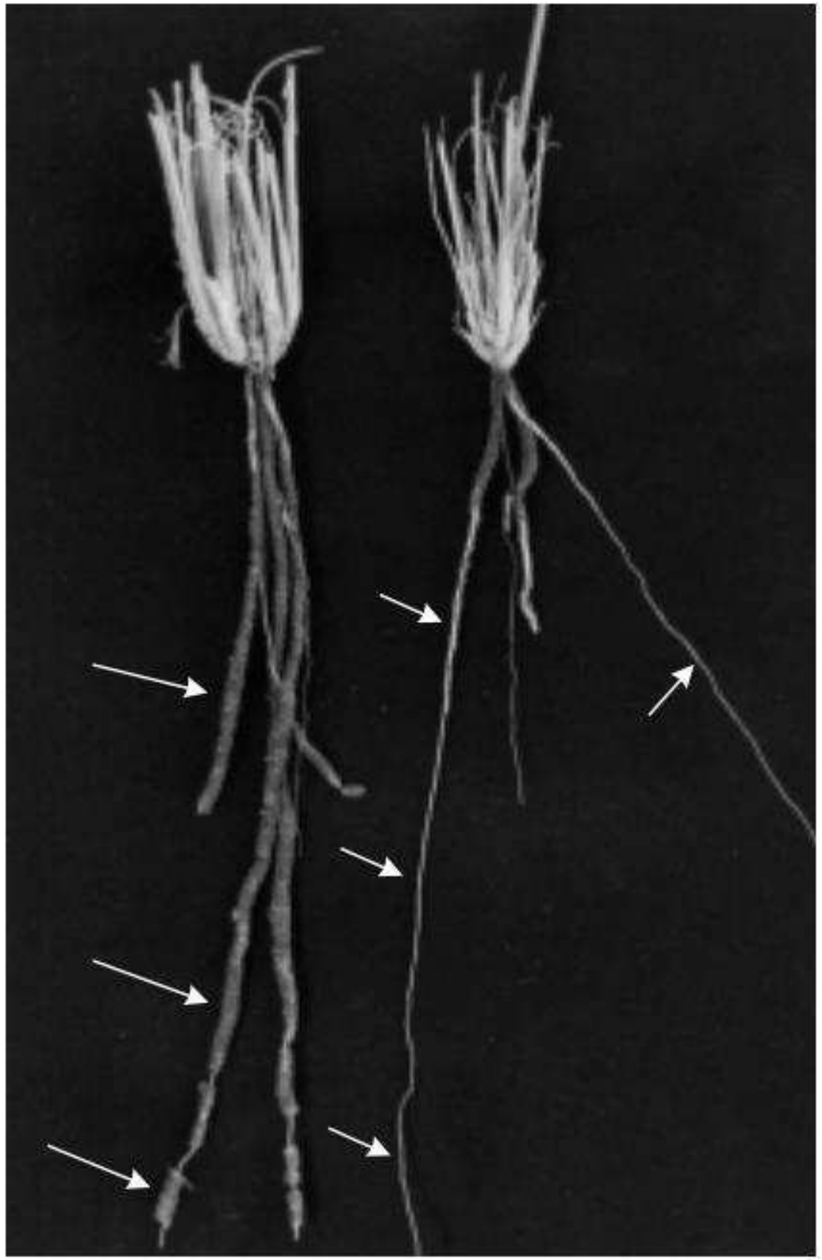


Fig. 7. Examples of a *Stipagrostis uniplumis* plant from outside (left) and inside (right) a mature, barren patch. Note the extensive coating of the roots with tenaciously attached sand (left, long arrows) compared to the uncoated roots of the plant growing inside the patch (right, short arrows).

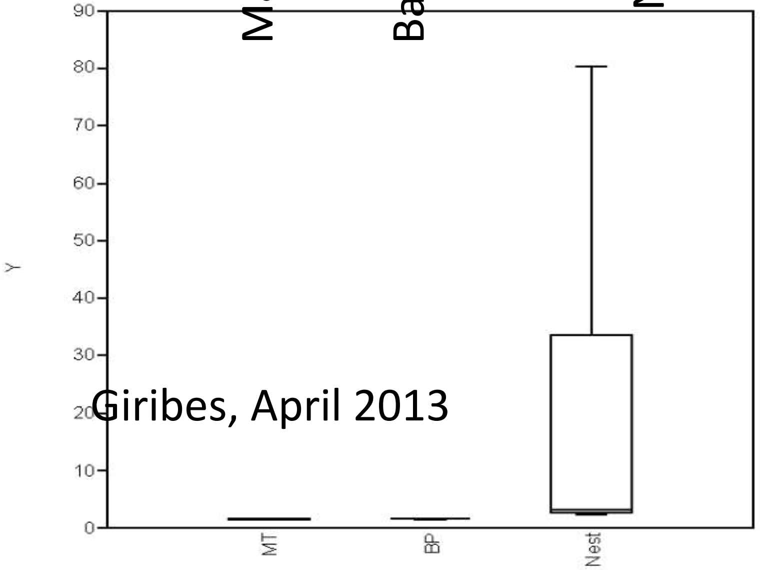

1mm


Plumula
Caryopsis
Roots
1mm



Gas vents

Methane production



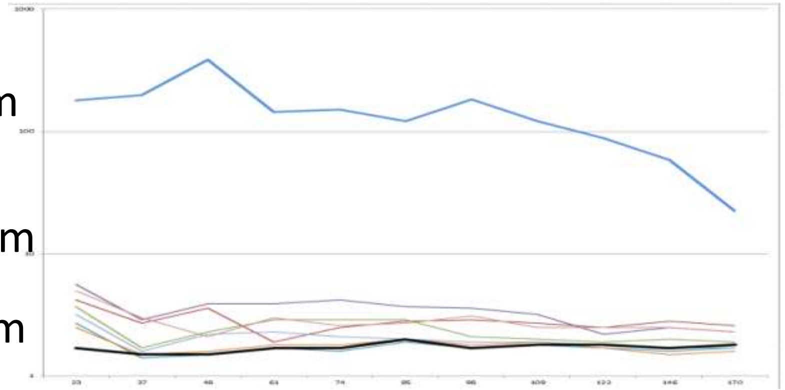
Giribes, April 2013

Methane is produced by living termites

1000 ppm

100 ppm

10 ppm



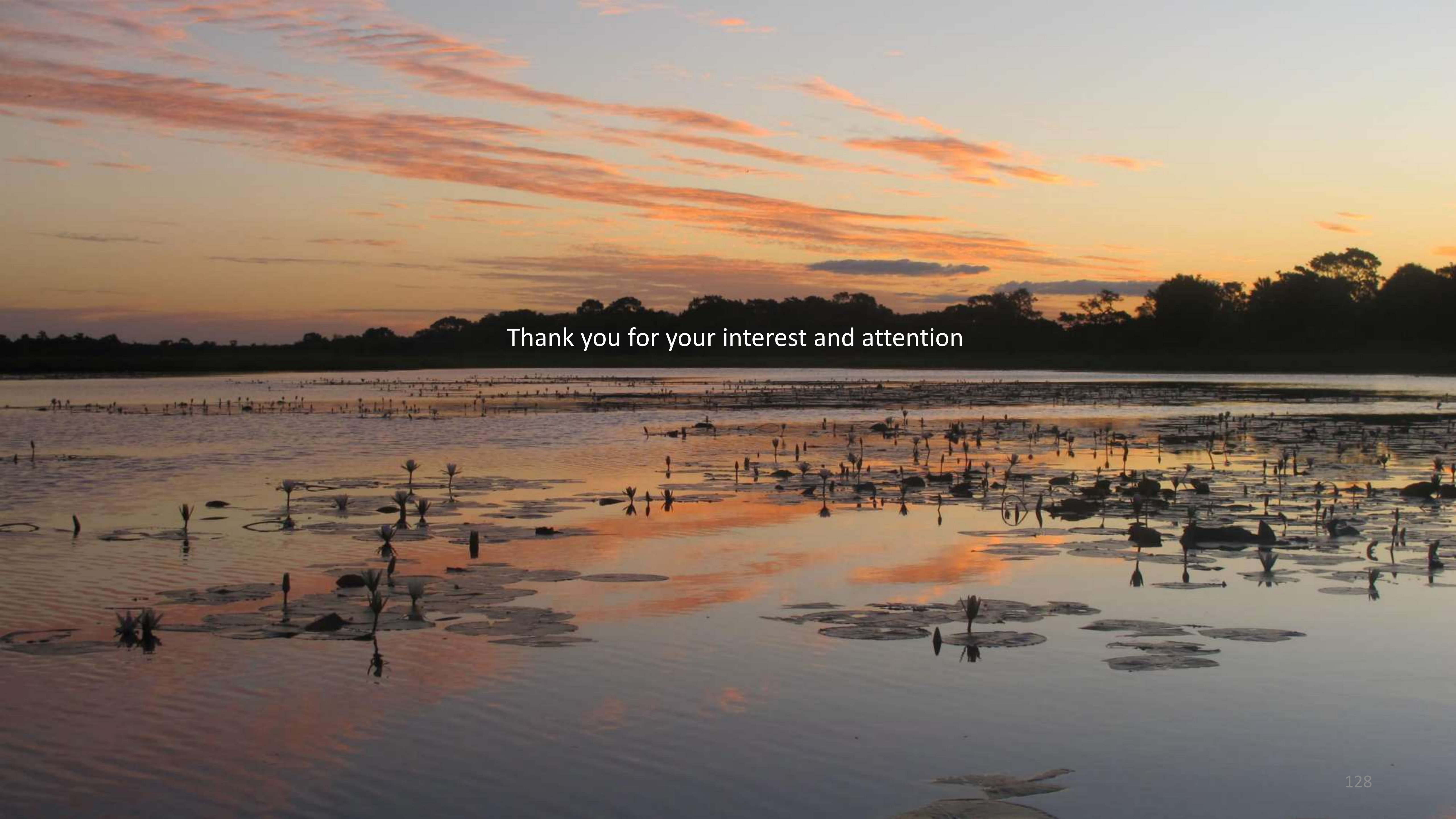
Dieprivier, October 2013

Similar problem: The langiage of the bees and the research by Max von Frisch

Checklist: Confirmed evidence

1. Type locality fairy circles inhabited by sand termites
2. Sand termite fairy circles occur in Angola, Namibia and South Africa
3. Soil beneath fairy circles most of the time moister than soil beneath matrix vegetation, even during extended periods of drought
4. Extremely slow water movements in sand dryer than 5 Vol%
5. Annual dieback starts in the centre and then progresses towards the margin
6. Annual dieback of grass happens in moist soil
7. Dieback of grasses is accompanied by expansion of sand termite tunnel system
8. Damage of the grasses and other plants by sand termites is shown


Thank you for your interest and attention


Thank you for your interest and attention